POWER

Vol. 40 NEW YORK, OCTOBER 20, 1914 No. 16

Killing the Goose That Laid the Golden Egg

Adelaide Municipal Tramway Power Plant

By F. G. Moffitt

SYNOPSIS—The plant consists of three 1500-kw., 11,000-volt turbo-generators carrying self-contained exciters. To prevent rushes of over-superheated steam, special thermo buffers have been erected. There is also a superheat alarm when the steam temperature approaches a dangerous limit. The six 1000-hp. boilers operate at 200 lb. pressure. The furnaces are equipped with chain-grate stokers.

The power plant of the Adelaide Electric Tramway, at Port Adelaide, South Australia, is designed to generate electrical energy at 11,000 volts and to transmit it by a duplicate overhead transmission line to two converter stations, a distance of about ten miles. Eight miles of this line will be overhead work and two miles will consist of underground cables. Five miles from the station a junction line connects with No. 2 converter station, which is three miles distant.

The site of the power house has been chosen with a view to the most economical coal-handling arrangement, and also for securing an ample supply of condensing water from the river.

During the work of excavation for the foundation, more than 600 piles were driven to the limestone bed 30 ft. below the ground level, and 27 ft. below the high-water mark, for the purpose of securing sound foundations for the heavy machinery to be installed. The preliminary work was particularly difficult, owing to the subsoil of soft mud and quicksand.

Turbines

In the turbine room, Fig. 1, there are three 1500-kw., three-phase, 11,000-volt turbo-generator sets, each having a 95 per cent. power factor, and guaranteed to give a 25 per cent. overload for two hours. The speed of each is 1500 r.p.m.

Each alternator carries a self-contained exciter, fitted with a compensating winding, which automatically adjusts the 100-volt exciting current at any load.

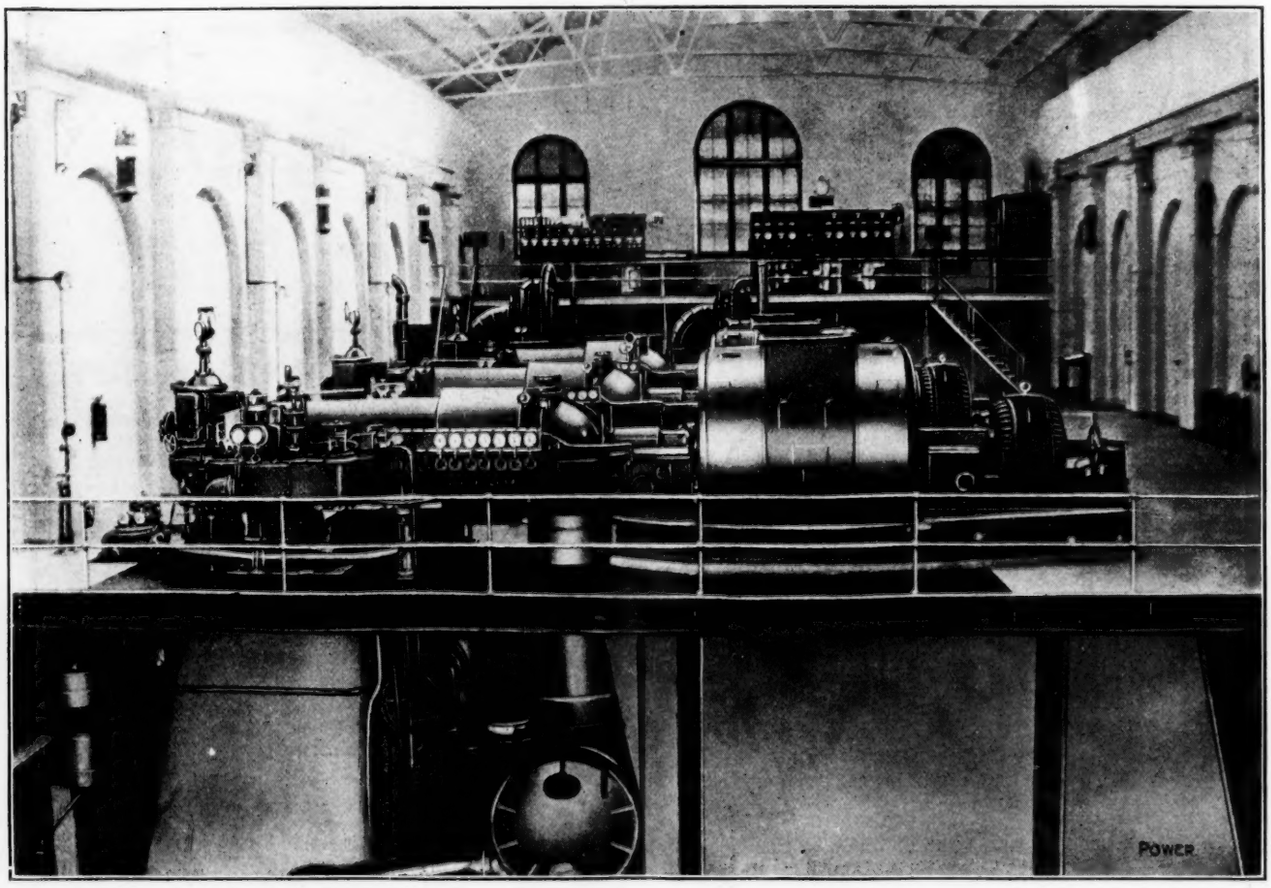


Fig. 1. Turbine Room of the Adelaide Municipal Power Plant

In the basement, under the turbines, are the main condensers and air pumps. The circulating cooling water, brought from the Adelaide River for the condensers, is returned through an outlet conduit, and discharges into the river 300 ft. from the inlet conduit. The cooling water is supplied by an electrically driven centrifugal pump which draws the water from the conduit below the engine-room floor.

To prevent sudden rushes of over-superheated steam

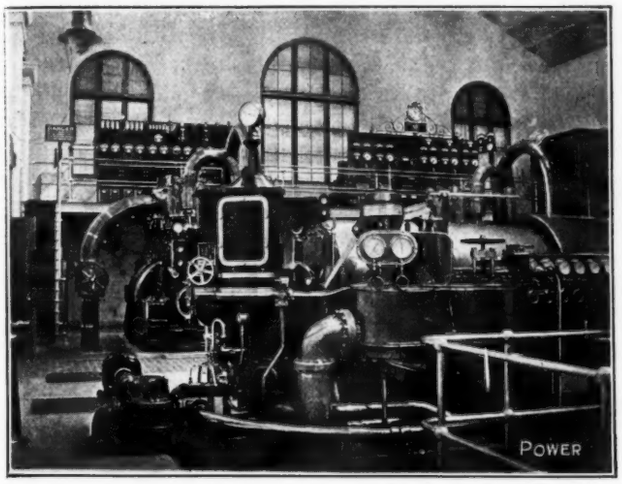


FIG. 2. STEAM END OF TURBINE AND THE ENGINE-DRIVEN SET

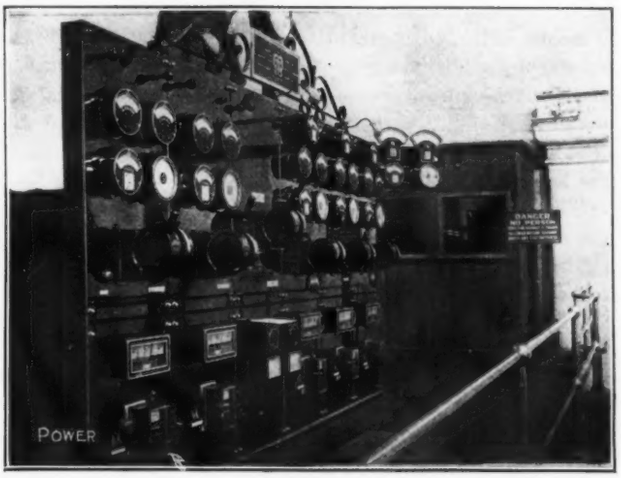


FIG. 3. ALTERNATING-CURRENT SWITCHBOARD

into the turbine, special thermo buffers have been erected. In addition, there is a superheat alarm which operates when the steam temperature approaches a dangerous limit.

The lubrication of the turbine is a special feature, the cooling oil being pumped from a well under the turbine, and after passing through the bearings at about 6 lb. pressure it is returned to the well after passing through a cooling chamber.

All auxiliaries are driven by direct-current motors at 200 volts supplied by a 200-hp. unit, Fig. 2, which also supplies energy for station lighting. The alternating-current switchboard, Fig. 3, is foolproof, the live parts being covered with armor plate and inaccessible to all except the electrician on duty. The main switches are of the oil-brake type, relays being fitted to the transmission lines and arranged to throw out the oil switches in case of trouble on the line.

BOILERS

There are six 1000-hp. water-tube boilers, Fig. 4, the largest of their kind in Australia. Each furnace is fitted with twin automatic chain-grate stokers with a ratio of 1 to 50 of heating surface. Superheater tubes raise the temperature of the steam to 630 deg. F., with a working pressure of 200 lb. per sq.in. There are 216 tubes in each boiler and 104 superheater tubes. By special arrangement, the temperature of the steam may be

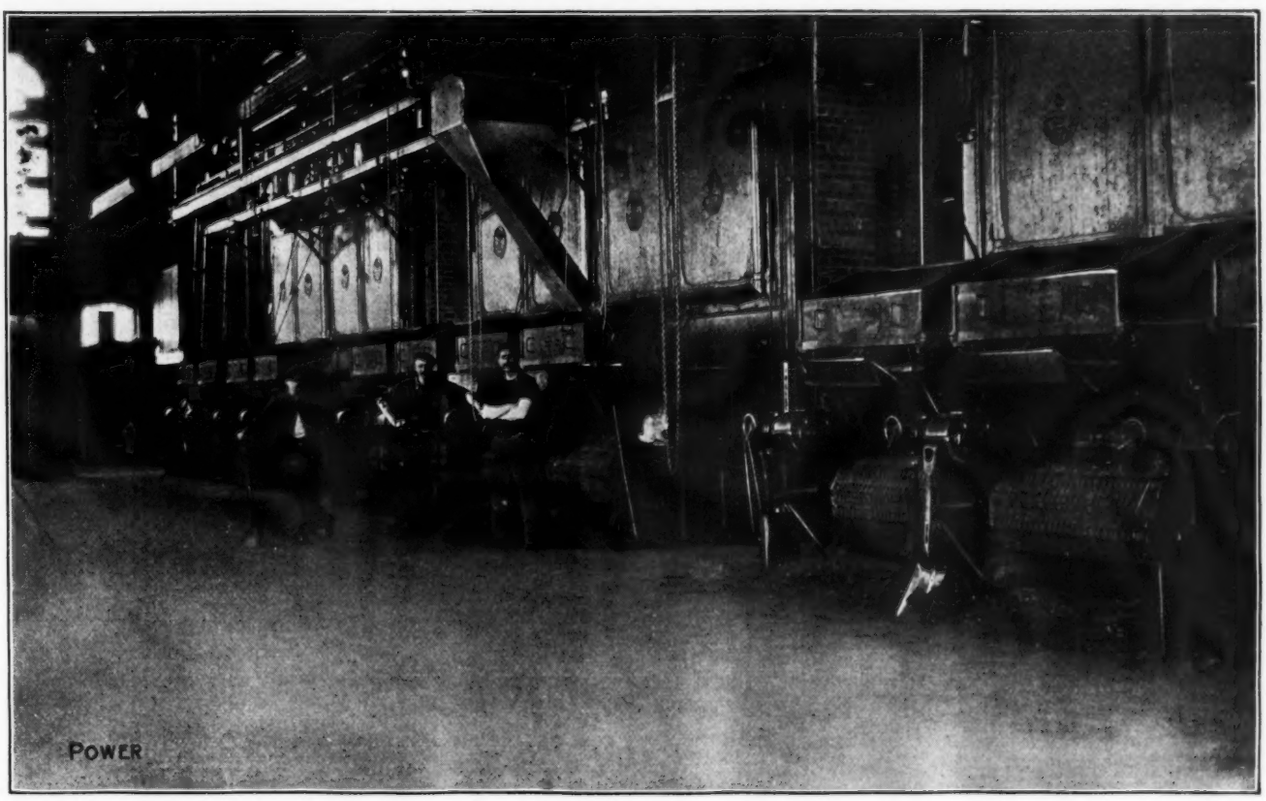


FIG. 4. BOILER ROOM, SHOWING CONVEYOR AND WEIGHING SCALE

regulated from the engine room to suit the requirements. The hot gases which are driven off from the fires are deflected by special dampers into the economizer chambers at the back of the boilers. The economizers are arranged in three groups, with 222 tubes in each and heat the feed water to a temperature of 300 deg. F. before it enters the boilers.

The stokers are chain driven from a shaft running the length of the boiler house and situated in the ash runway. There are three speeds and a neutral which allows the stokers to travel at from 1 to 8 ft. per hour.

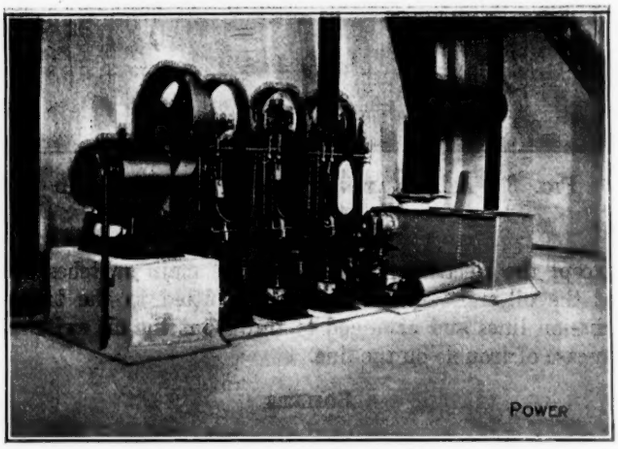


FIG. 5. FEED-WATER PUMP AND LEA RECORDER

Should any of this gear get out of order, a patent release clutch is introduced, which throws the grate out of action.

Each boiler is fitted with two 6x6-ft. steam drums, lying across the two main drums. One is connected to the saturated steam and the other to the superheated steam pipe; the main take-off pipe is fitted between them with a butterfly valve, so that if the superheated steam rises too high this valve may be opened to admit saturated steam, thus keeping the steam down to the required temperature.

PIPING

Feed water is delivered from the main water supply into a 4000-gal. tank through a valve operated by a float. From this tank it flows into a makeup tank and then goes through a softener to the hotwell, where it is pumped to a feed-water heater, then to the economizers, and into the boilers. All makeup water is metered by a recording meter, Fig. 5.

The main steam line is next to the engine-room wall, and from one end of it a pipe containing a reducing valve which reduces the pressure to 100 lb. runs to the auxiliary steam units. The main supplies to the turbine are tapped off from the main steam line and go through the wall below the engine-room floor, the supply being controlled by a main stop valve close to each turbine. On the main steam line a recording thermometer is installed which leads to the engine room, and if the steam raises too high an alarm is sounded, denoting which boiler is above normal in temperature. There are two main boiler feed pumps placed side by side at the west end of the boiler room and adjacent to the hotwell from which the water is drawn. Next to the feed pump is the feed-water heater, which uses exhaust steam from the 250-hp. engines.

Fuel is brought into the yard and dumped into a hopper, from which it gravitates through crushers, driven by a 20-hp., compound-wound, 200-volt motor, into a 400-ft. bucket conveyor. Each bucket holds about 80 lb. of coal, and it requires eight minutes to make one revolution. The conveyor is driven by an 8-hp. motor. The coal is conveyed to the storage bunkers above the boiler house, each bunker having a capacity of 1400 tons. From the bunkers the coal is drawn off and automatically weighed by a traveling weighing machine. The fuel then falls through a chute into a small hopper above the stokers, from whence it goes to the grates and is fed to the furnace as required. The capacity of the bucket is 40 tons per hour. The bunkers are so arranged that there is a separate one for each boiler. The special weighing machine below the bunker is electrically operated and passes from boiler to boiler as required.

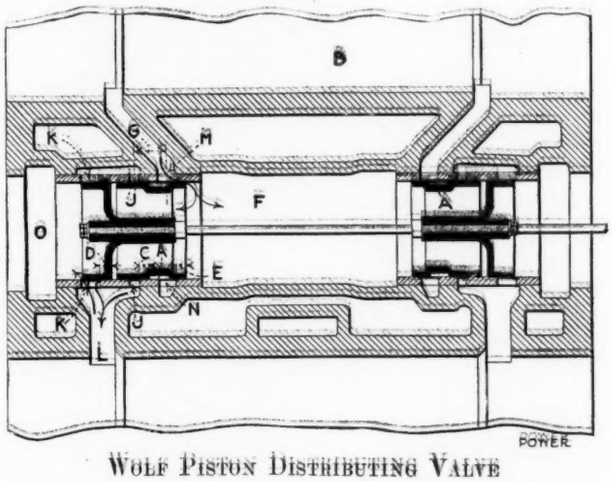
ASHES

The ashes are disposed of by opening a trap at the back end of the grate, where they drop into a hopper in the ash runway and are removed at the end of each shift.

Furnace gases go to a steel stack of the self-supporting type. It is 200 ft. high and 24 ft. outside diameter at the bottom, and is bell-shaped for 50 ft., then straightens the remaining 150 ft. with an inside diameter of 12 ft. The draft on a normal day is 1 in. This steel stack is one of the largest in Australia.

Wolf Piston Distributing Valve

A recent patent granted to Rudolph Wolf, Magdeburg-Buckau, Germany, is for a piston distributing valve for compound engines arranged to work in common to the high- and low-pressure cylinders. The valve has channel-



WOLF PISTON DISTRIBUTING VALVE

shaped passages through it for distributing the exhaust steam from the high-pressure and the admission of steam to the low-pressure cylinder.

The accompanying illustration shows a section through a distributing valve designed with an annular recess *A*, which remains in communication with the high-pressure cylinder *B* and allows the exhaust steam to pass directly from it to the low-pressure cylinder when the valve in moving from its middle position has traveled through the distance *C*, corresponding with the lap *D* for the remaining opening of the valve.

After the valve has moved from its middle position through the distance *E*, the supply of steam is admitted from the high-pressure cylinder *B* into the receiver *F*, through the passage *G*, as indicated by the arrow. The admission of steam into the low-pressure cylinder *H* begins through the ports *J* and *K* and through the port *L*, as indicated by the arrow, after the valve has moved from its middle position through the distance *C*.

The advantage consists in a diminution of the distance *M* between the steam outlet port *N* of the high-pressure cylinder *B* and the steam inlet port *J* to the low-pressure cylinder *H*, and in a reduction of the number of places to be kept steam-tight. There is also a reduction in the losses of pressure and heat during the period steam is supplied to the low-pressure cylinder, as a greater part of the working steam not passing through the receiver goes from the high- to the low-pressure cylinder.

Because of this the advantage of the Wolf engine with respect to the steam supply by the shortest way is had, while the disadvantage—the interdependence of the steam distribution in the high- and low-pressure cylinders—is avoided. This is owing to the choice of varying laps and that the steam in passing through the receiver is given an independent exhaust from the high-pressure and an independent admission into the low-pressure cylinder.

Will Quizz, Jr.

SYNOPSIS—Chief Teller is reminded of a promise to tell about the mechanical equivalent of heat and explains the subject in an elementary way.

"Chief, you promised to tell me about the relation of heat to mechanical energy; how about it?"

"Will, heat is just work—through and through. It can't keep from work. In fact, as soon as heat is liberated from the coal it gets busy at once—and works! Get that! It heats air and all the material near-by, but we are most interested in its action on the water in the boiler. The first action is that it makes each molecule more energetic. While these molecules do not change form (from water to steam) at once, they vibrate against each other more and more rapidly as heat is applied.

"In fact, Will, the wise ones say that everything solid, liquid or gas is made up of molecules, which are always in motion so long as they contain any heat at all (above absolute zero). Of course, this motion is not perceptible, but it has been proved by a process of reasoning by the scientific fellows. The molecule itself is the smallest bit of a thing which has been broken all to smithereens!

"Pretty small sample, Chief!"

"Yes, but the wise ones know. Anyway, suppose each particle of water to be separated to itself. As it became heated it would expand and require more room, and in order to get it, it would have to push some of its next neighbors away. What is that action?"

"Why, that's work, isn't it?"

"That's right. As the water expands it is lighter for the space it occupies, and it rises toward the surface, where it has less pressure about it, but it still has the air pressure (14.7 lb.) Other particles in turn get heated and act the same way until they have absorbed enough heat energy to overcome the air pressure. Then they will change their form from water and become steam. Each molecule must expand against the pressure of the air, and as the total surface exposed to the air pressure becomes greater, it means more work, which requires more heat.

"When it gets to be steam, the molecule is nearly 1700 times larger than when it was water, and in expanding so much there has been a lot of work done. The quantity of this heat energy used depends on the amount of external force (pressure) it has to overcome—that it has to push back and the distance—to make room for itself. It is our old acquaintance *foot-pounds* again. If it has the atmospheric pressure only to work against, it requires a certain amount of heat energy, but as the pressure increases, it has to have more heat energy because of the greater work it has to do.

"We know that if we burn coal under the boiler and make steam, which is used in the engine; that is, converting heat into energy in the ordinary way. But along in 1840 to 1849 an Englishman, Doctor Joule, proved that heat was not a material substance, as was then commonly believed, but *energy* which could be applied to, or taken away from, bodies. So he got busy and devised a means to determine the mechanical equivalent of heat; that is, how many foot-pounds of energy there were in one B.t.u., or how many B.t.u. in a given number of foot-pounds."

"That was some stunt, Chief. How did Joule do that?"

"One rig he used was a copper cylinder having fixed baffles or vanes inside and a vertical shaft in the center, with paddles attached to rotate between the baffles.

"With water in the cylinder there would be considerable resistance. He wound a cord around a spool on the upper end of the shaft, passed the end over a pulley and attached a weight to it so that the weight in lowering would rotate the shaft and paddles; this would absorb power in agitating the water, which in turn caused the water to heat.

"Joule then put into the cylinder 1 lb. of water which was at the temperature of 39 deg. F. Then he put on a weight and wound it up to a certain point—and let 'er go. When the weight had lowered to a certain mark, the thermometer in the water showed that its temperature had increased 1 deg. He next got busy with a stub of a pencil and multiplied the weight in pounds by the number of feet the weight had lowered—foot-pounds of work required to produce the 1 deg. change in temperature. He verified this in a great many different experiments and established what is known as Joule's law of the mechanical equivalent of heat.

"Later, experiments with more refined apparatus showed that Joule's figures were probably a little low and now 778 foot-pounds is accepted as the mechanical equivalent of 1 B.t.u. The other way round, each B.t.u. should produce 778 foot-pounds of work, which would be the case if none went astray in the process of transfer. But they certainly do get lost in the shuffle.

"So you see, Will, there is nothing very difficult to understand about the mechanical equivalent of heat."

The Unaflow Engine in Europe

By A. D. Skinner*

The American engineer who travels Europe, not as a sight-seeing tourist but with a view to studying engineering practices, is frankly dumbfounded when he realizes how far in advance of his native country the Europeans are in respect to power-plant engineering and efficiency. The mediæval may exist in their castles and old ruins, but not in their power-plant equipment.

This superiority exists not because there are better engineering brains in Europe than in America, but because they have no cheap fuel. Necessity has forced them to conserve their natural resources, of which fuel is the most valuable; and competition in the building of prime movers has developed the fact that it does not cost very much more to install a plant that develops a brake-horsepower-hour on 8 or 9 lb. of steam than to build one that uses twice or three times that amount.

It is one thing to demand an economical plant but quite another to make sure that you have it. Therefore, nearly every steam engine installed in England and on the Continent is tested for economy by the purchaser after he has operated it a few months, and before he has made final payment.

The maintenance of economy is often assured by having the plant tested every few years. The result is that engine builders fight over a difference of a few grams in their economy guaranties. Several engine builders, both in England and on the Continent, informed the author that only in exceptional cases did the purchaser accept an engine without making an economy test.

Maintenance of high economy rather than first cost is therefore the factor that decides the selection of prime movers.

Germany seems to have taken the lead in the development of power-plant efficiency. That they have been working along these lines for years is exemplified in the power plant of the Wertheim store in Berlin, where the engines installed 14 years ago are still delivering a kilowatt-hour on less than 3 lb. of coal.

The development of the power-plant industry in Germany has been truly wonderful; and, without statistics at hand, the author feels safe in saying that Germany is building a greater horsepower of engines than the United States. Of the many engine factories visited, the smallest employed 700 men, while several had from 1400 to 2000 men on their pay-rolls.

This large output of engines requires a corresponding output of electrical machinery; and Germany has two electrical concerns, each larger than the largest electrical manufacturing company in this country. One employs 79,000 men, and the other 83,000. Their combined annual output is valued at $197,000,000.

Where do all these engines go? On account of the steady industrial growth of Germany, a great many do not go outside of the confines of the empire. The power companies, which are for the most part municipally owned, and almost without exception profitably operated, are not permitted to make discriminatory rates in favor of the large consumer which force the helpless small consumer to pay for the resultant loss.

The result is that the small consumer gets his current at less than half the charge made in the United States, the large consumer makes his own power, and the publicly owned power companies are making money.

The power equipment not used at home is exported to all parts of the globe. As every American engine builder knows to his sorrow, the Germans have taken from him practically all his export trade in South America, China, Japan, Russia and Africa, largely because they build a more economical engine.

People who installed power plants 14 years ago, which still develop a kilowatt-hour on less than 3 lb. of a rather poor grade of coal, would probably not be content with even this remarkable achievement; and it is therefore interesting to learn what they have been doing since that time.

They have developed a single-cylinder engine with two inlet valves, and no exhaust valves—unless the piston may be called such—which gives as good economy as a triple-expansion engine with 12 valves, together with the consequent complicated gearing.

Moreover, this engine uses practically no more steam per indicated horsepower-hour at one-fourth load than at full load, making it unequaled for variable loads.

A test on an 18x20-in. Unaflow engine, by Prof. Bache, of the Technical High School of Copenhagen, in 1910, showed a steam consumption per i.hp. per hour of 9.0, 9.3, 9.5 and 9.7 lb., with the respective loads of 116, 149, 184 and 222 hp. The engine, of course, was operating condensing and with superheated steam. Tests on a 300-hp. Unaflow engine have shown a steam consumption as low as 8.8 lb. per i.hp. per hour.

The Unaflow engine is no longer an experiment in Germany, but is built by practically all of the leading engine builders. So far over 1,000,000 hp. is in actual operation.

Gebrüder Sulzer have built, at the Ludwigshafen Works, over 60,000 hp. of Unaflow engines, and while the author was in their plant, he was informed that they had orders on their books for 30 Unaflow engines, some as large as 2000 hp.

Ehrhardt & Sehmer, of Saarbrücken, who employ 2000 men in their excellently equipped shops, have built nearly 200,000 hp.; and to them belongs the credit of building the largest Unaflow engine in existence. This engine is of 6000 hp. nominal capacity, and is installed in the plant of Gebrüder Röchling, at Völklingen. It is directly connected to a train of rolls, and is capable of giving an economy of 8.5 lb. of steam per i.hp. per hour.

The load on this engine fluctuates from 0 to 6000 or 7000 hp. every few minutes; and the designing and building of a single-cylinder engine to operate under these severe conditions, and at the same time to give the highest economy under all conditions of load, represents one of the greatest steam-engineering feats ever recorded. On account of its immense size, the engine is very poorly depicted in Fig. 1.

The first locomobile builders who adopted poppet valves and Unaflow cylinders were the Maschinenfabrik Badenia, at Weinheim, who have now built over 1000 poppet-valve Unaflow locomobiles, of a total capacity of 200,000 hp.

*Vice-president, Skinner Engine Co.

Fifty in different stages of completion were to be seen on the author's visit there.

The adoption of the Unaflow principle for locomobiles in Germany was undoubtedly hastened by the publication in the *Zeitschrift des Vereines Deutscher Ingenieure* of a series of tests, after several years' operation under average operating conditions, on twelve different locomobiles, where the average fuel consumption was found to be 5.92 lb. per kw.-hr., when operating condensing and with superheated steam.

Unaflow steam cylinders are now being extensively used on air compressors in Germany, being ideal for this service on account of the high economy under intermittent loads.

The Prussian Railway has in operation fourteen Unaflow locomotives, and has since purchased sixteen more, after many careful tests, which have demonstrated a saving of nearly 30 per cent. over the counter-flow type.

Unaflow locomotives are now being used extensively by both the Russian and Austrian railways, and England is testing out her first Unaflow locomotive.

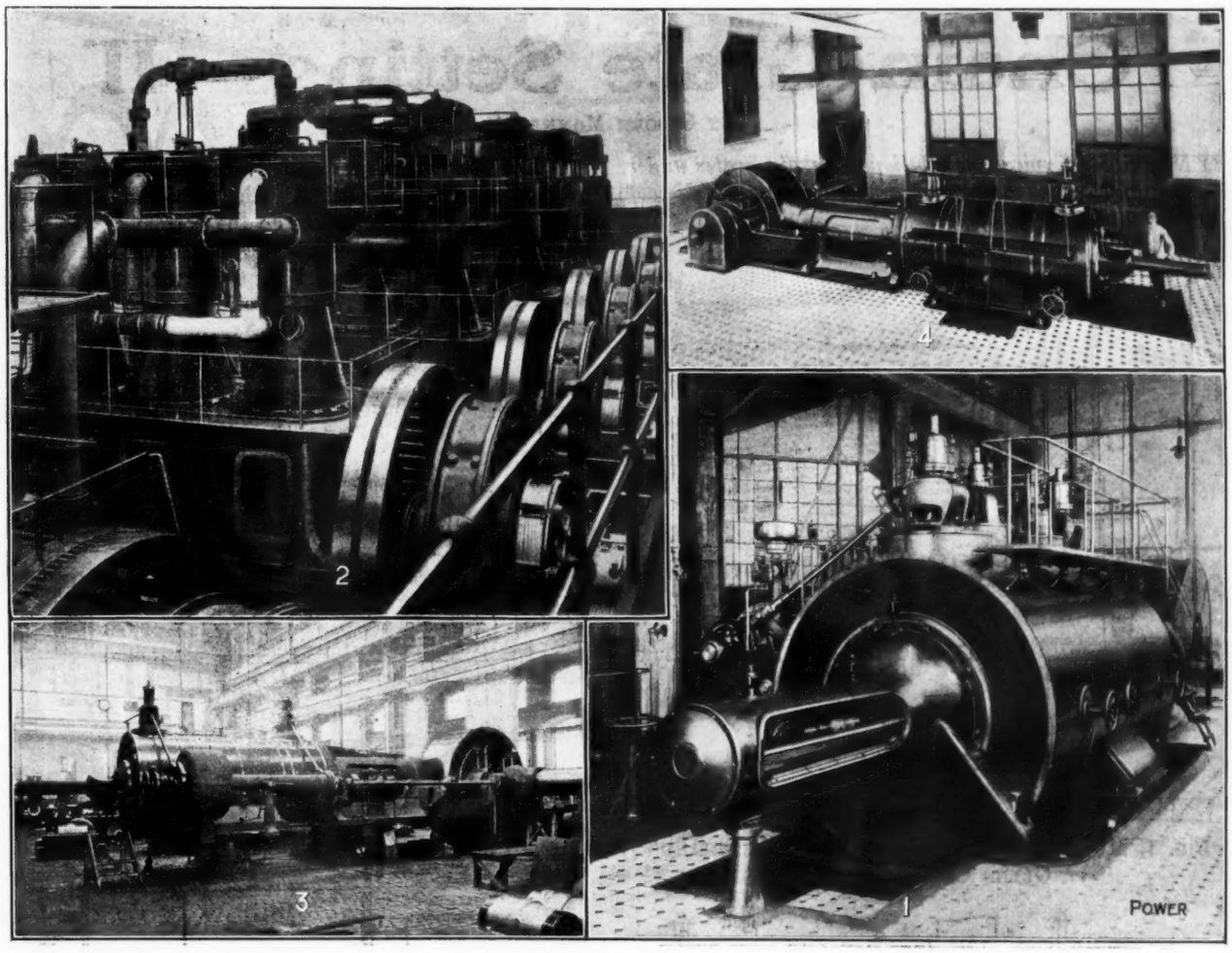
The best evidence of German activity is found in the fact that, while the Unaflow principle is old, its practical application to steam engines was not seriously attempted until four years ago*; and, in this short time, the Unaflow has made serious inroads upon the counter-flow steam engine.

England was not many months behind Germany in the adoption of the Unaflow engine; and already many thousand horsepower have been built, both for home consumption and for eastern colonies.

Fig. 2 shows an interesting replacement in the plant of the Salford Corporation, where three steeple-compound cylinders on a 1200-hp. engine were replaced with Unaflow cylinders. The original engine consumed 25.35 lb. of steam per kw.-hr., which is equivalent to 15.8 lb. per i.hp.-hr.; while the Unaflow, on test, obtained a steam consumption of 17.45 lb. per kw.-hr., or 10.9 lb. per i.hp.-hr. This was with 150 lb. working pressure, 25 in. vacuum, and only 80 deg. F. superheat. The purchasers expect to replace the compound cylinders of their five remaining engines with Unaflow cylinders.

The American who visits William Jessups & Sons, Ltd., Sheffield, will find that the last engine they installed was a Unaflow; and, if he inspects the municipally owned central-station plant at Sheffield, he will be chagrined to see a 500-kw. compound Corliss engine, of American manufacture, that has not been in operation since they installed a Unaflow engine a short time ago.

One English manufacturer, who builds both steam turbines and Unaflow engines, recommends the latter type



THE UNAFLOW ENGINE IN EUROPE

Fig. 1. Six thousand horsepower in a single cylinder. Fig. 2. Unaflow engine in foreground replaces steeple compound. Fig. 3. A Sulzer Bros. Unaflow. Fig. 4. Typical German Unaflow installation.

*This article was written more than a year ago. There are even more Unaflow engines now than the writer counts.

for capacities of 750 kw. and less, but states that above these sizes the increased cost of land, building, foundations, etc., due to the installation of the reciprocating engine, more than offsets the gain by reason of better economy.

In Germany and Belgium, however, the reciprocating engine seems to have the preference over the turbine, even in capacities up to 1500 kw. In comparing the Unaflow to the turbine, it should be remembered that practically all the steam plants in Europe are operated condensing, and the noncondensing turbine is nowhere in evidence.

The value of superheat, even for small plants, was realized many years ago, and one will have to go far in Europe to see a modern plant operating with saturated steam; the result being that the Corliss valve was largely superseded by the poppet valve on large stationary engines, and by the expanding piston valve on the locomobiles.

Now that the three largest locomobile builders have adopted the poppet valve, this type of valve is left in undisputed supremacy on the Continent, and is the typical European valve.

Chain-Grate Settings--II*

By Osborn Monnett†

SYNOPSIS—Typical installations of chain grates under horizontally baffled boilers of different types. Tile-roof furnaces and vertical baffles.

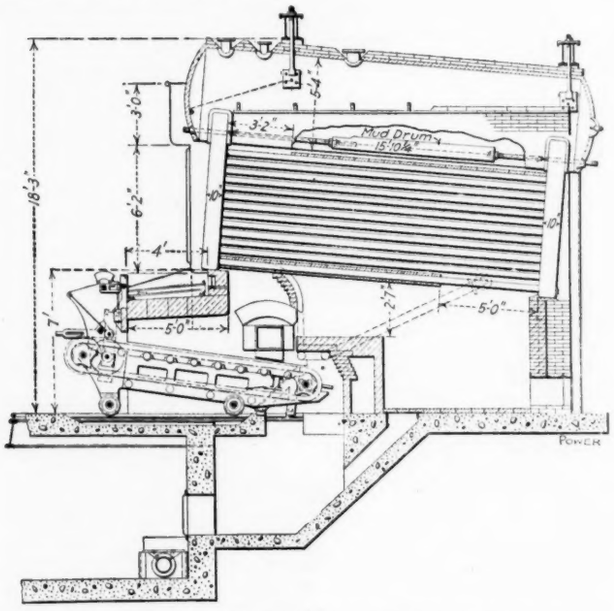


Fig. 1. Murray 300-Hp. Water-Tube Boiler and Green Chain Grate

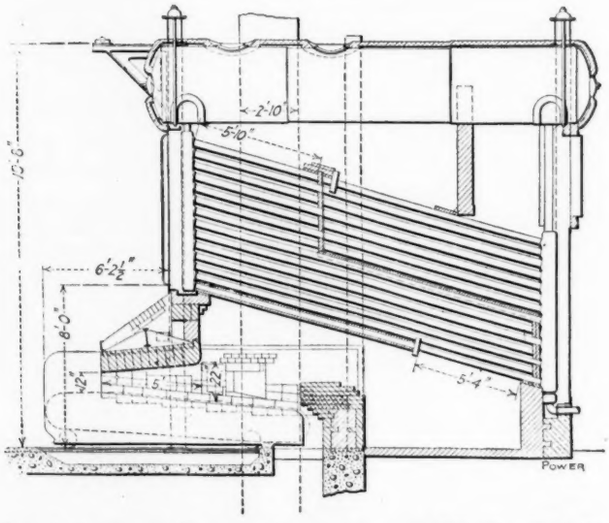


Fig. 2. Laclede-Christy Stoker under 500-Hp. B. & W. Boiler with Sewell Baffle

It is a simple matter to apply the chain grate to the ordinary Heine type setting. The important dimension is the distance from the floor to the bottom of the front header, and for good operating conditions this should generally be not less than 7 ft. 6 in. with a horizontal

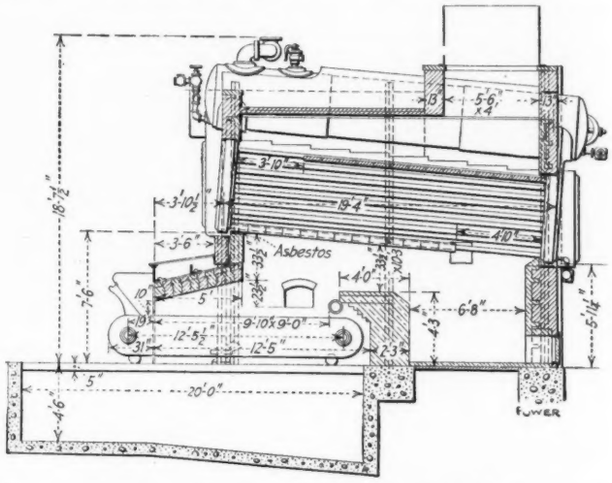


Fig. 3. S. & S. Chain Grate under 463-Hp. Heine Boiler

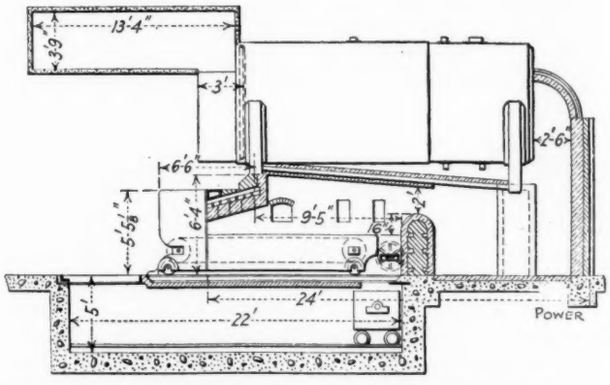


Fig. 4. Lyons 360-Hp. Boiler and McKenzie Chain Grate

grate or 7 ft. with an inclined grate. Fig. 1 shows a typical installation consisting of an inclined Green chain grate and a Murray water-tube boiler. As the grate is inclined, the head room for the setting is reduced to

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†Smoke inspector, city of Chicago.

ft. without restricting the area over the bridge-wall, which in all cases should be at least 25 per cent. of the active grate surface. Installations of this kind should never be made flush front, as this arrangement does not give the flame travel required before the gases come in contact with the heating surface. The illustration shows a minimum 5-ft. arch and a 4-ft. extension from the gate to the front header. High-pressure water-backs, such as are shown in this illustration, are considered good practice, as they form a rigid and permanent support for the bridge-wall.

Fig. 2 shows a 500-hp. B. & W. boiler with a Laclede-Christy chain grate having a head room of 8 ft. under the header. With this type of boiler, which has a tube pitch in excess of other horizontal water-tube boilers, 8 ft. is the minimum head room which should be allowed with the horizontal baffle. This obviates the danger of restricting the opening over the bridge-wall and the combustion chamber itself, which would tend to "bottle" the heat, with disastrous effects on the brickwork. This illustration shows the Sewell baffle. With natural draft, it is not advisable in the average case to use this baffle on boilers less than 14 tubes high, as the restriction in the gas passes will reduce the capacity and increase the maintenance cost. This baffle "kills" the pull of the stack and does not allow sufficient draft over the fire to accomplish the desired results. With a 14-tube high or a double-deck boiler, Sewell baffle works out well.

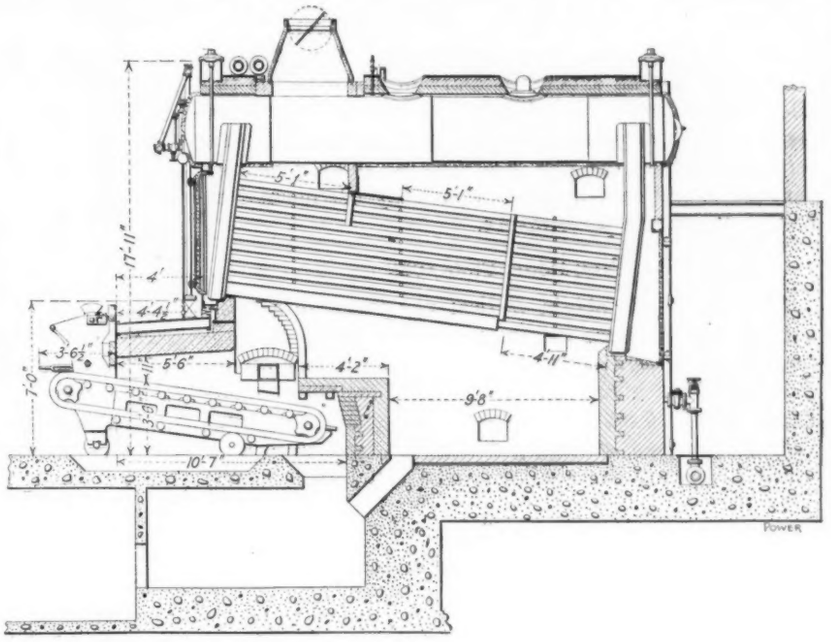


FIG. 7. ERIE CITY BOILER, 326 HP., WITH TWO ROWS OF TUBES BARE FULL LENGTH. LACLEDE-CHRISTY STOKER

Figs. 3 to 6 illustrate horizontally baffled boilers of different types. The head room varies with the type of boiler and the pitch of the tubes. All of the boilers can be installed with the head room for the furnace varying from 7 to 8 ft., the average being about 7 ft. 6 in. for the ordinary installation.

With the long run of baffling forming a tile roof over the combustion chamber, the temperature in some cases becomes so high as to cause an excess maintenance charge for brick work. To relieve this, the expedient shown in Fig. 6 has been adopted with success. In this installation, with a head room of 6 ft. 6 in. under the front header, the box tile on the front end of the lower tubes

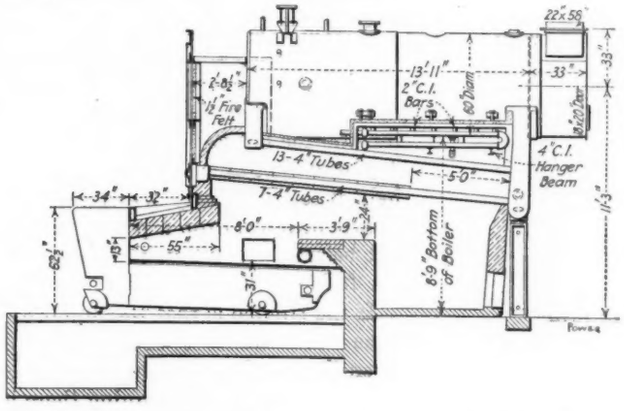


FIG. 5. HAWKES BOILER, 150 HP., WITH SUPERHEATER AND CONTINENTAL CHAIN GRATE

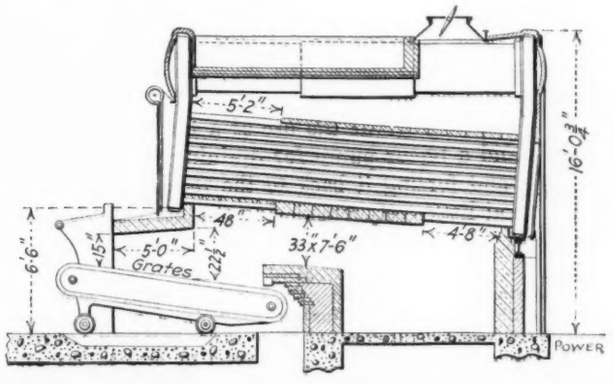


FIG. 6. EDGE MOOR WATER-TUBE BOILER AND GREEN INCLINED CHAIN GRATE

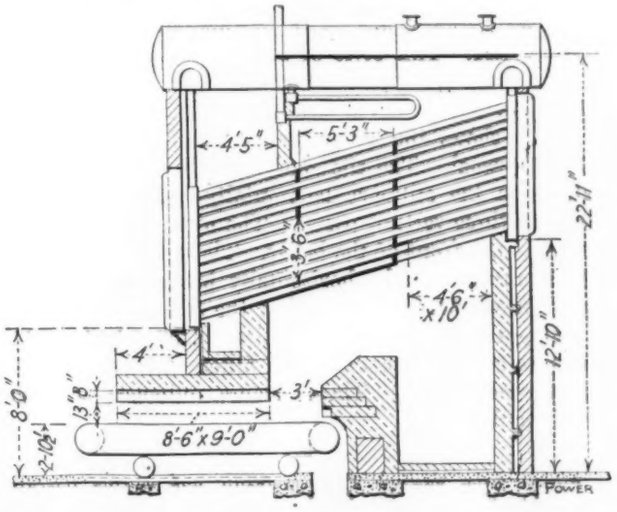


FIG. 8. B. & W. BOILER, 500 HP., VERTICALLY BAFFLED WITH TILE-ROOF SETTING AND B. & W. STOKER

has been removed for a distance of 4 ft. and T-tile substituted. This increases the heat absorption by the tubes and lowers the temperature of the furnace to a point where the brickwork can stand it. Apparently it has no detrimental effect on the smoke performance. In traveling along the heating surface, the flame is not "killed" as rapidly as when passing into a bank of tubes. Consequently, with the chain grate, a horizontal run of tubing can be bared to an extent necessary to maintain the furnace temperature at a point low enough to prevent excessive wear and tear on the brickwork. Fig. 7 shows a setting in which the first two rows of tubes have been bared for their full length without any detrimental effect on the smoke performance.

Tile-Roof Furnaces

It is possible to obtain vertical gas passes in a boiler and at the same time get the long flame travel given by the horizontal-pass baffle, by using the tile-roof setting shown in Figs. 8 and 9. Fig. 8 shows the stoker under the back end of the boiler directly under the mud drum, and the tile roof extending to the first gas pass, after which the passes are similar to the standard vertically baffled water-tube boiler, with the flue gases taken off at the back end. This style of setting has given good satisfaction on high capacities when ample head room was obtainable.

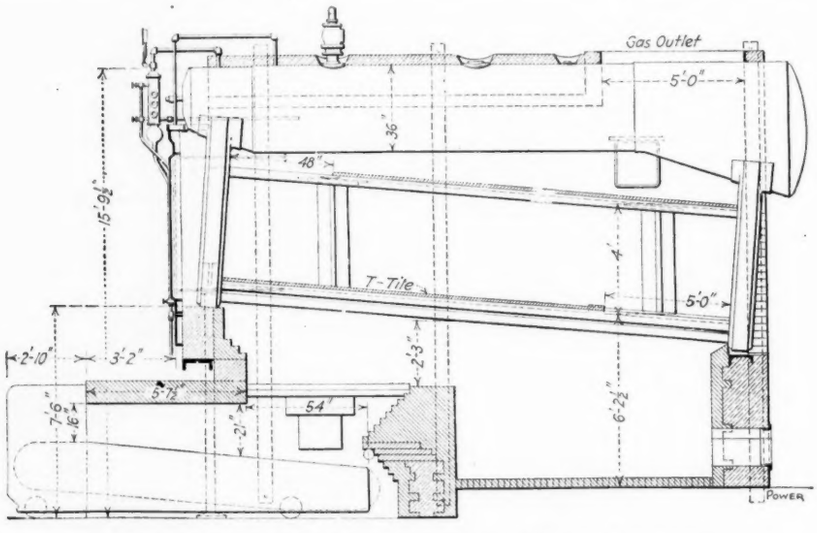


Fig. 9. Geary 410-Hp. Boiler and Green Inclined-Chain Grate with Bement Tile-Roof Setting

Fig. 9 shows the stoker under the front end of the boiler as usual. The tile roof extends over the bridge-wall as in the ordinary horizontally baffled boiler, and there are three vertical passes. The uptake is around the drums at the front of the boiler. These settings have all the advantages of the horizontally baffled boiler in the way of flame travel, etc., and at the same time have the advantages accredited to the vertically baffled boiler. The examples given are boilers with different tube pitch and stoker construction. These factors influence the head room required.

⁂

Power from Sewage Gas—A 16-hp. gas engine operates regularly on sewer gas in the sewage pumping station at Paramatta, Australia, says a correspondent in "The Power User." The gas is drawn directly from the septic tanks through 3000 ft. of pipe.

Why Ammonia Disappears from the Receiver

In the operation of a refrigeration plant, the liquid ammonia sometimes gradually disappears from the receiver, and many are puzzled to know where the liquid has gone.

The most frequent cause is the storing of the liquid in the ammonia condenser, if this apparatus is made of two or more pipe coils. This condition is brought about by the uneven distribution of the hot ammonia vapor throughout the condenser coils, and this action is in turn greatly influenced by the uniformity of the distribution of the cooling water through or over the coils, depending on what kind of condenser is used. If any one or more coils are furnished a greater quantity of water than others, or are so located as to receive a smaller amount of hot vapor, a lower pressure will be created in this section of the condenser, causing a flow of liquid into it from the liquid main.

It often happens that the flow of liquid into one or more sections is so strong that some of the ammonia vapor is drawn through the liquid outlet of one or more of the other sections or stands. This may be detected by the heating of these connections. When these pipes are closed off, the hot vapor, coming in larger quantities into the condenser in which the liquid is stored, will force the liquid back into the receiver, sometimes filling it.

Usually it is difficult to overcome this trouble, although it is due mostly to improper equalizing of pressure in the high-pressure end of the plant. One will often find it helpful to throttle the hot-gas valves in the condenser so that each is open about one-half turn. This may make the condenser pressure drop a pound or two, but better distribution of the gas often follows this action.

If the trouble is that the liquid has gone into the direct-expansion coils when these coils are below the suction line of the compressor, the reason for it remaining there is generally because these coils have frosted or become covered with ice, which prevents active evaporation of the liquid in the coils. If the liquid stores in the condenser coils, it usually returns from time to time to the receiver, but when it stores in the cooling coils it disappears gradually and remains in them until they are defrosted or the liquid is pumped out.

Many engineers favor the use of a low-pressure liquid receiver and a liquor pump for draining the liquid from the coils and forcing it back to the receiver. This may be put in at little cost, considering the convenience which it affords.

⁂

Removing Rust—Articles attacked by rust are said to be conveniently cleaned by dipping them in a well saturated solution of stannic chloride, 12 to 24 hours sufficing according to the thickness of the rust. An excess of acid in the solution must be avoided. After the objects have been removed from the bath they must be rinsed with water, then with ammonia, and quickly dried. They are said then to resemble dead silver.—"Iron Age."

What the CO_2 Shows

and Why It Is High or Low

This Combustion Guide Sheet tells what troubles to look for and where and what they may be as indicated by the CO_2 in the Flue Gases.

FOR *a given kind of fuel and load on the boiler there is a boiler draft (pressure difference between the furnace and uptake) that will give the best combustion. The greater this difference the greater will be the volume of gases passing over the heating surface, and the greater the volume the more rapid will steam be made, provided that not more excess air than practically required is admitted to the furnace either from above or below the fuel bed.*

Causes of Low CO_2

Excess Air **Insufficient Air** **Improper Mixture of Air and Gases**

Principal Troubles

Causes of Excess Air

1. Leaky boiler setting.
2. Too thin fire.
3. Holes in the fire.
4. Draft too strong.

Causes of Insufficient Air

5. Too thick fire or bed of ash.
6. Insufficient draft.
7. Grates plugged with ash or slag.
8. Too thick covering of fresh coal.

How to Remedy the Troubles

1. Leaky Boiler Setting: Find the leaks with a lighted candle held close to the brickwork and doors while the dampers are open. The flame will be drawn in at the leaks. Plug the cracks or holes with waste and asbestos mixed with thin fireclay. If desired, paint brickwork with thin fireclay.

2. Too Thin Fire: Reduce the draft or carry thicker fuel bed.

3. Holes in the Fire: Cover and level the fire evenly. Clinker may be holding grate open. Air spaces plugged in places giving too strong draft in others. Air spaces in grate or at dead-plate too large for size of fuel.

4. Draft Too Strong: Carry a thicker fire or reduce the draft. Lumps of coal too large, allowing air to pass too freely through fuel bed.

5. Too Thick Fire: Increase the draft or carry thinner fire.

6. Insufficient Draft: Too thick fuel bed. Air spaces in grate plugged with slag or too small for size and character of fuel. Dirty flues, tubes or both. Doors open in setting, flue or chimney base or air duct. Damper stuck or not open wide enough due to stretch of operating cable. Nozzles of steam jet plugged with baked soot or alkali or air intakes for jets partly or wholly closed. Chimney and flue overloaded.

7. Grate Plugged with Slag: (Causes) Ash fuses and becomes plastic. Parts of fire turned over when using slice bar putting ash on top of incandescent coals, melting it. Furnace temperature too high owing to ignition or combustion arches or tile on lower row of tubes being too close to the grate. Expose all or part of lower row, putting tile on next row above. Shorten combustion arch but first make sure that low ash fusing point is not due to mixture of two or more kinds of coal. If ash fuses below 2000 deg. F. it is too high in sulphur, iron, alumina or silica and coal with ash having a higher fusing point should be used.

8. Too Thick Cover of Fresh Coal with Too Little Air Admitted Above the Fire: Volatile driven off so fast that not enough air comes through grate for its combustion. Either cover lighter or provide for admitting and properly distributing air over the fire. If much smoke is still produced and gases are high in CO use a lower volatile coal.

CAUTION.—Don't fill holes in the fire with fresh coal; level the fire first.

How to Make Solutions for the Orsat

Solution for Oxygen: Put 1 oz. of pyrogallic acid (powder) into a quart of water; pour in a pint of caustic solution (see solution for CO_2) and immediately seal the bottle air-tight until used.

Solution for CO_2. Dissolve 1 lb. of caustic potash in $2\frac{1}{2}$ pints of water.

Solution for CO. Acid cuprous chloride is used and may be made as follows: Put a $\frac{1}{4}$-inch layer of copper oxide in the bottom of a quart jar. Put in a bundle of a dozen lengths of No. 10 or 12 gage bare copper wire, cut in length equal to depth of jar. Fill the jar with hydrochloric acid, seal and shake occasionally for forty-eight hours. Pour off clear solution in clean bottle and seal.

Motors, Their Principles and Uses - V

By Gordon Fox

SYNOPSIS—Mechanical features of a motor installation, including methods of mounting and type of drive. Charts are included for determining pulley and belt data and selecting the proper gear ratios.

Motors may be mounted upon driven machines or upon the floor, side wall or ceiling, and may drive through couplings, gears, chains, belts or rope transmissions.

When mounted upon the floor, it is best to use a base or provide some means of keeping the motor above the dirt and moisture with sufficient space for sweeping. A base is better than rails, especially where the floor is uneven, due to the tendency of rails to settle away from a plane surface. Motor bases should be heavy enough to retain their shape under stress. A good method of insuring permanent alignment is to fasten the base down by lag screws, try out the motor and determine its final position, then pour lead around the lag screws, filling in the space in the bolt holes. Large motors may be neatly installed by providing a concrete foundation and anchor bolts, the motor being aligned with wedges and grouted in. Most motors are built with considerable end play. By magnetic attraction, the rotor and the stator are drawn opposite one another when in service, and if the shaft is not level, two opposing forces act upon it and an end pound results.

Motors may be readily arranged for side-wall suspension by shifting the bearing brackets through 90 deg. They are sometimes attached to the ceiling for driving through the floor to machines above. As the motor usually has a small pulley, it is necessary in such cases to bear in mind that the weight of the belt decreases the tractive power. It is not good practice to hang small direct-current motors directly from the ceiling, as they are inaccessible and do not receive proper attention; some sort of rack should be provided.

Direct-connected motors are best mounted as to be intrinsically a part of the driven machine. This is advisable for the sake of retaining alignment, but is not always necessary. Usually some form of bracket or platform is arranged, and if it is not possible to attach this to finished surfaces, it may be bolted to any part of the machine. The motor may be aligned and the bracket forced into position with wedges. A dam is then placed around the feet of the bracket and any spaces filled with lead.

Couplings

Flexible or solid couplings may be used for direct-connected motors. Flexible couplings should be used wherever there is vibration in the driven machine, where there is any possibility for relative movement of motor and machine, and where an end thrust occurs which might be imposed upon the motor; they may also be used as insulators. The most common kinds are, leather-link and leather-laced belt couplings and rubber-buffer couplings. The leather-link and rubber-buffer types are commonly used in small and medium sizes, while the leather-laced type finds favor for more severe work. There is some difficulty in securing uniform rubber which will retain its elastic properties. Leather couplings are not suitable in the presence of flying grit, oil or moisture. Solid couplings of the flange and compression types are the most commonly used.

Belt Drive

Belt drives are simple, flexible, inexpensive and elastic, affording protection to the motor in case of overloads and shocks. The drive occupies considerable space, however, is not so positive, and has a relatively high maintenance cost. Belt drives are undesirable for widely fluctuating loads, as heavy tension must be maintained for carrying the peaks and the losses under the light loads are proportionately high.

The power which can be transmitted by a belt varies with the speed, increasing nearly in direct proportion until a linear speed of about 4500 ft. per min. is reached. Beyond this, on account of increased centrifugal stresses, the effective transmitting power is reduced. Belt speeds between 2000 and 4000 linear ft. per min. are conservative values. Ordinarily, about 1000 ft. per min. is the minimum and 5000 ft. per min. the maximum. It is most economical to operate belts within the range of conservative speeds, due to lower first cost and maintenance and minimum power loss. Where very low speeds are used, wide belts are required. The center of the belt then overhangs the motor bearing some distance and trouble may ensue. Decrease of contact surface means higher belt stresses, due to greater tension required to prevent slipping. Wherever possible, the lower side of the belt should be made the driving side, so that the sag may be at the top. In determining pulley sizes, the allowable clearance and the belt speed are factors to consider, as well as the arc of contact on the smaller pulley.

The chart, Fig. 1, will be found useful for determining pulley and belt data. Consider that the speed of the driven machine and its pulley size are known. Find the intersection of the horizontal line representing pulley diameter and the diagonal representing speed. The vertical at this point represents belt travel. Follow this line to the diagonal of motor speed and the intersection will be on the horizontal giving the motor pulley diameter. Returning to belt travel, ordinarily follow this to the horizontal line representing 180 deg. arc of contact on the smaller pulley, then proceed along the diagonal to the horizontal representing the actual arc for the case in question, which can be readily approximated. Now follow the corrected vertical to the curve for type of smaller pulley used, and the horizontal line at this point will show the horsepower per inch width of belt desirable. From this the values of belt width and pulley face may be determined.

Single leather belts should, in general, be used for widths up to 6 in. and for use on pulleys less than 9 in. in diameter. Double leather belts should be used for most other installations except the very large, when triple belts may be used. Rubber belts are elastic, durable even under adverse conditions of temperature and moisture, have good tensile strength and are uniform in width and thickness; their tendency to stretch, however, is often a disadvantage. Laced belts should not be used for motor drives; endless belts are preferable. Belts should run

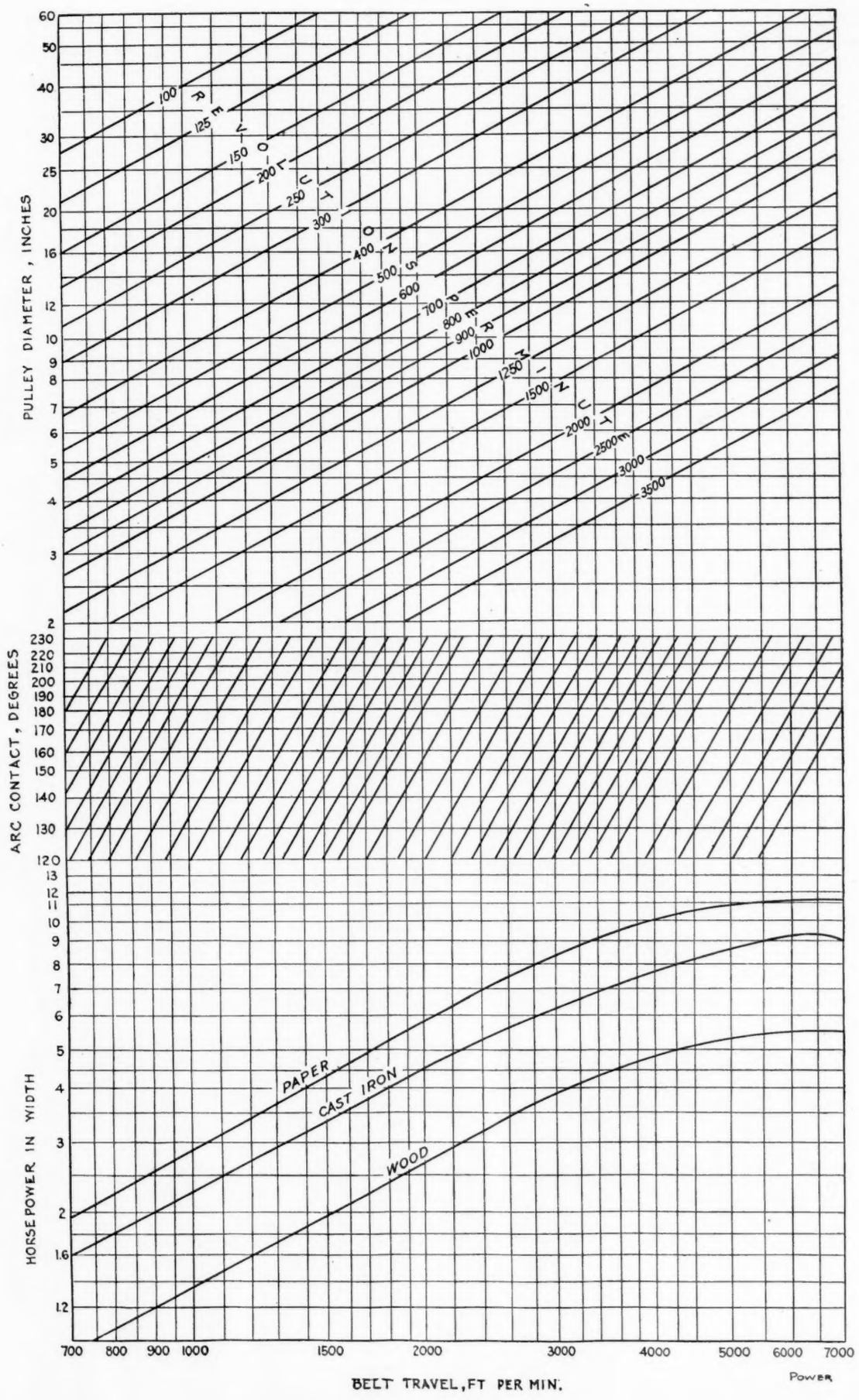


FIG. 1. CHART FOR DETERMINING BELT AND PULLEY DATA

with and not against the lap at the joint, and the joints should be smooth to prevent jarring. The wobbling of belts is sometimes due to pulleys having unlike crowns. Flapping is usually caused by slippage between some portion of the belt and pulleys, resulting from grease spots on the belt. A back-and-forth movement of the belt at the pulley is caused by the edges of the belt being of unequal arrangement. If the shafts are parallel, but the pulleys not directly opposite, the belt will run to one side of the larger pulley. If the pulleys are opposite, but the shafts not parallel, the belt will tend to run to one side of the smaller pulley.

The distance between centers of the motor and driven shafts depends upon the relative elevation of the smaller pulley and whether the belt pulls on top or bottom. The distance should be such as to allow a gentle sag. Five times the diameter of the larger pulley is usually a safe distance, provided the difference between the sizes of pulleys is not too great.

The maximum advisable ratios of reduction through a single set of pulleys are: 8 to 1 for motors about 5 hp., 6 to 1 for about 10 hp., 5 to 1 for 20 hp., and 4 to 1 for about 50 hp. If it is desired to ascertain the smallest pulley under which the motor bearings will give service, this may be done by figuring the total belt tension required, according to the formulas given below:

For iron pulleys,

$$tension = \frac{3 \times horsepower \times 33{,}000}{belt\ travel\ in\ ft.\ per\ min.}$$

For wood pulleys,

$$tension = \frac{2 \times horsepower \times 33{,}000}{belt\ travel\ in\ ft.\ per\ min.}$$

Knowing the tension at the center of the pulley, the distances between bearings and the overhang to the pulley center, the shaft may be considered as a simple lever, and the thrust on the bearing next to the pulley determined. The thrust per unit of projected bearing area may then be figured if the bearing dimensions are known. For motors under 50 hp., the pressure per square inch bearing area should not exceed 70 lb. For larger motors, pressures up to 100 lb. are allowable under favorable circumstances. Since belt tension must increase rapidly with a decrease of diameter, the limitations imposed by the bearings are usually the factors determining minimum diameter and maximum face.

Where there is insufficient space between the pulley centers to permit an open belt, or where the ratio of speed reduction desired is too great for open belting, or where a compact drive is desired, a belt-tightening device on the motor is warranted. As it affords good arcs of contact, low tensions may be used, and there is little or no loss in efficiency. Due to the elimination of the cost of a long belt, the drive is usually no more expensive than a simple belt drive. The ability of the belt tightener to decrease slippage and to lower maintenance expense as well as to increase reliability should recommend its use in many cases.

Gear Drive

Gear drives are positive, compact and well adapted to slow-speed work. They have fair efficiencies, ranging from 92 to 98%, but require careful alignment, are usually noisy and transmit all shocks to the motor. The allowable ratio of reduction is limited by the surface speed of the gear, the number of teeth and the pitch diameter. For small motors, a 10 to 1 ratio is allowable, and for moderate sizes, 8 to 1 is the maximum ratio permissible. The minimum number of epicycloidal teeth advisable for a pinion is 12, but with annular or internal gears, the pinion may have as low as eight teeth. When driven by a larger gear, the minimum number of epicycloidal teeth is 14. In calculating a given gear reduction, the gear should, if possible, have a prime number of teeth, so that shocks due to a repeated cycle of operations may be distributed; the use of an odd tooth prevents the same teeth from coming into mesh so often.

Gears are usually of cast iron or cast steel with cut teeth, while the pinions may be of steel, brass, fiber, raw-

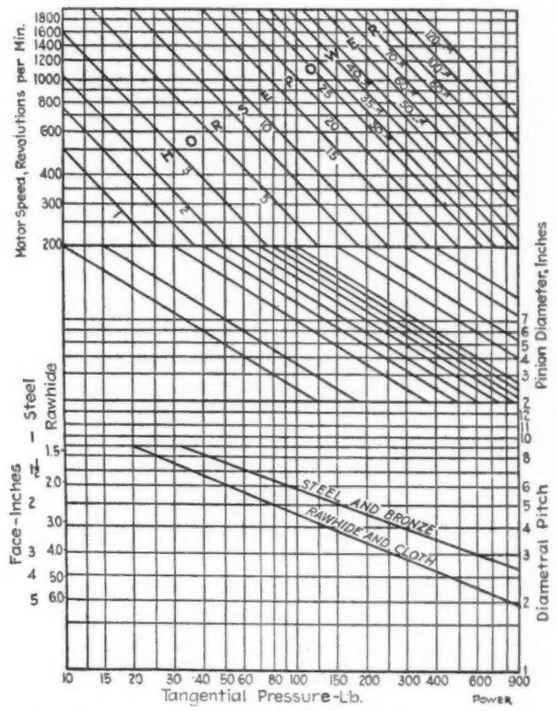


Fig. 2. Chart for Computing Gear Drives

hide or cloth, the latter types usually having end plates of brass. Steel pinions have excellent life and are not affected by temperature or moisture, but are noisy and cut quickly unless well lubricated. Steel gears are about twice as strong as cast iron and should be used when the face of the corresponding cast-iron gear would be 4.5 in. or more. The cost of cast-steel gears is nearly double that of cast-iron gears. The pinion is subject to the most rapid wear, due to its smaller diameter; therefore, it is important to have a pinion of good wearing qualities as well as of sufficient strength.

Iron and steel gears ordinarily become noisy at about 800 ft. per min. linear surface speed, but may not become disagreeably noisy below 1200 ft. per min., or even higher.

Where it is desired to attain high surface speeds without noise, brass, fiber, rawhide or cloth pinions may be used. Brass pinions, although somewhat quieter, have shorter life than steel. They are particularly adapted to conditions of heat and moisture prohibiting the use of a nonmetal pinion, but where noise is objectionable. Fiber pinions are quiet, but are not very rugged and are subject to deterioration by moisture. Rawhide pinions are satisfactory unless subjected to extremes of heat or mois-

ture or excessive load fluctuations or frequent starting, stopping or reversing. For equal strength, the face of rawhide pinions must be about 25 per cent. wider than corresponding steel pinions. The surface speed of a rawhide pinion is limited more by rapid wear than by noise. A speed of 2000 ft. per min. is a fair average limit, but 2500 to 3000 ft. per min. may be used under favorable circumstances of attendance and lubrication, in the absence of moisture and for intermittent service where the life of the pinion is not important. Cloth pinions are quiet, not easily affected by heat or moisture, are quite elastic and give good service even when subjected to strains and shocks. The allowable surface speeds correspond to the values for rawhide. Where quiet operation is desired, it should be noted that rigid and massive supports and close-fitting bearings both on the motor and driven machine are conducive to a noiseless drive. The pinion should always be placed as close as possible to the motor bearing.

Fig. 2 will be found useful in the selection of gears. Usually the horsepower, speeds and approximate distance between centers are given. With the gear ratios and center line distances given, an approximate pinion diameter may be selected. To use the chart, find the intersection of the horizontal line representing the motor speed with the horsepower diagonal. From this point follow the vertical of torque to the horizontal representing 1 ft. pinion radius, then follow along the diagonal to the horizontal representing the pinion diameter selected. The vertical at this point represents the tangential pressure at the pitch line. Following this vertical to the curves for steel and rawhide pinions, the approximate diametral pitch and gear face can be determined. The nearest commercial size that will give a good number of teeth should be selected.

Gears must be kept well oiled, and at high speeds some method must be used, the effectiveness of which will not be destroyed by centrifugal force. Rawhide gears should not be oiled, but should be lubricated with talcum and graphite or graphite and lard oil.

Worm gears are used for special cases where a large speed reduction is desired. They are positive, quiet and free from vibration. They have low efficiencies, ranging from 70 to 80 per cent., and require excellent machining and good lubrication. A carefully adjusted end thrust bearing must also be provided. The worm should mesh with the bottom of the gear and should run in oil. If the worm is placed above the gear, it will not receive good lubrication. The best rubbing-surface speed for worm gears is about 300 ft. per min., although speeds as high as 700 ft. per min. are sometimes permissible. Worm gears are not reversible; that is, the wheel will not drive the worm. They can sometimes be used in a braking capacity due to this feature.

Friction drives are useful where power is to be transmitted at high speed and low torque, for small amounts of power and where it is desired to change the speed or throw into and out of gear while in motion.

Chain Drive

The silent chain drive is excellent for many applications. It is quiet and efficient, and permits of compact layouts. Moreover, it can be used for wide reduction ratios, particularly where the motor cannot be placed close enough for gearing. It is a positive drive and does not afford protection to the motor through slippage. Its first cost is high and the expense of maintenance is usually greater than that of belts.

The center line distances for silent chain drives should be approximately equal to one-half the combined sprocket diameters plus half the diameter of the larger sprocket. In a vertical drive, the small wheel should not, if possible, be the upper one. Where feasible, it is best to have the pull on the bottom of the chain. To provide for elongation, particularly in vertical drives, where the chain tends to fall away from the lower sprocket, a sliding base should be used. The driven wheel should be flanged. Where the load is of a pulsating character, it is well to use a driven sprocket with a spring center to absorb fluctuations. Chains and wheels should be protected from dirt. When operating at speeds above 1300 ft. per min., they throw off their lubricant, and therefore should be inclosed and should run in oil.

Ordinary square-link chains are used for very slow-speed drives. They are cheap, positive, not affected by moisture and can be used in place of belts under heavy tension. Moreover, they do not require maintained lubrication. They are rated by numbers, as given in the following tabulation:

LINK CHAIN DATA

Chain No.	No. Links in 10 Ft.	Average Ultimate Strength in Lb.
25	133	700
35	74	1,200
45	74	1,600
55	74	2,200
66	60	2,600
75	46	4,000
85	30	7,600
95	30	8,700
110	25	12,700

The formula for determining the horsepower capacity is as follows:

$$horsepower = \frac{ultimate\ strength \times travel}{factor\ of\ safety \times 33{,}000}$$

The factors of safety are as follows:

Travel, ft. per min.	200	300	400	500	600	700
Factor of safety	6	8	10	12	16	20

If the load is irregular or subject to shock, use higher factors of safety. The working load depends upon the speed and the character of the work. At increased speeds, the chain is subject to greater shock and requires higher factors of safety.

Shafting is used in motor application work largely for group drives. As a guide to the selection of sizes, the following table is included:

HORSEPOWER CAPACITY OF COLD-ROLLED SHAFTING FOR COUNTERSHAFTS

Shaft Diameter in In.	Revolutions per Minute 100	150	200	250	300
1 1/16	7	10	13	17	20
1 1/8	9	13	17	21	26
1 3/16	11	16	21	27	32
2	16	24	32	40	48
2 1/16	31	47	62	78	93

Bearings for countershafts should be spaced about 8 ft. apart. Where feasible, a countershaft should be provided with not more than three bearings. Pulleys should be placed close to the bearing, and if possible adjacent pulleys should pull in opposite directions.

Smoke Abatement on the Pennsylvania—D. F. Crawford, superintendent of motive power of the Pennsylvania Lines west, left on July 15 on an inspection trip over the lines to see what can be done in regard to the abatement of the smoke nuisance. Mr. Crawford is an authority on this subject, and has been interested in the abatement of locomotive smoke for more than 25 years.

The Cost of Power

By H. M. Phillips

SYNOPSIS—Discussing the distribution of charges in keeping power-plant accounts, the author favors a fixed charge for repairs instead of charging off amounts actually expended. Determining the cost of a kilowatt or horsepower-hour before and after purchasing power.

The cost of a horsepower is often difficult to determine with justice to all interested. Where power is bought from a central station at a fixed price per kilowatt-hour, the engineer and the accountant know exactly where they stand; the only difficulties lie in estimating the amount of power that will be required for new machines and in dividing the total charge among the different departments or pieces of apparatus. None of these problems is likely to prove serious, and the latter can be eliminated by the use of a sufficient number of meters.

The accounting department can determine satisfactorily the cost of a horsepower in an isolated plant. The cost of fuel supplies and labor cannot be disputed; to these are added a series of overhead charges which may nearly double the amount and may bring the total up to $60 or $100 per horsepower-year, a figure that the operating engineer is apt to consider excessive and which is generally too high to be used on all occasions.

The most troublesome items of the overhead charge are office expense, repairs and depreciation. The power plant usually requires a small part of the time of the company's officials and clerical force and no accounting can be correct without including it.

Where repairs are charged according to the amount actually expended, that amount necessarily fluctuates from year to year, making an irregularity where a fixed charge is decidedly preferable. When the fixed charge is used it should be considerably above the amount ordinarily expended from year to year to provide for the serious break that is likely to come sooner or later.

In regard to depreciation, the engineer may complain that his accounts are loaded heavily with this item in spite of the facts that, owing to the alterations and repairs which have been charged to the plant, it is actually in better condition than when first installed; that during the years it has been in operation it has paid a fair proportion of the cost of a new outfit on these charges. Granted that this is true, it is certain that the old plant will be abandoned or replaced, and that it should be made to pay for itself before that time comes. The proper method is to have the charge diminished from year to year, so that a plant whose theoretical life is nearly run will not have to pay the same as one in the beginning of its career; it should never be compelled to more than pay for itself on these charges.

Admitting that all of the foregoing items should be included in the cost of a horsepower and accepting the figures obtained by the auditing department, there are still many difficulties in applying the figures to cases that frequently arise to trouble the engineer. A central station offers to supply electric power at a considerably lower cost per horsepower-year or kilowatt-hour than the amount charged against the steam plant. This is brought to the attention of the engineer with the suggestion that he reduce his operating expenses; then serious talk of purchased power follows, and perhaps the change is eventually made. In many cases it doubtless pays to abandon the old plant, and it may be assumed that the saving is carefully and accurately estimated before this is done, but during the preliminary stages the cost of a horsepower, as figured in making up factory costs, is the incorrect basis of comparison.

Omitting accounting of the cost of new apparatus and of making the change from one system to the other, what is to become of the interest on the original investment that constitutes a fairly large item in the cost of a horsepower? What is to become of the depreciation charge? The old equipment will be worth practically the same five years from now as at present, not much above the price of scrap iron. Will all of the labor charged against the cost of a horsepower be dispensed with and no additional labor be required? Not unless the present system of accounting is extremely good. Steam will still be required for heating in winter and probably for other purposes all of the year; there is probably other apparatus that receives attention from the engine-room staff, and the electric power will require some attention. Admitting that under the present system, steam for heating, labor and other expenses not actually expended in the generation of power that is to replace electric power, are properly charged on separate accounts, can those accounts be carried at the same cost under the new system? The cost of heating will undoubtedly be higher, and probably most of the other items also. For a comparison with the cost of electric power, the engineer can safely estimate the cost of a horsepower as that of the fuel, labor and supplies; and he should probably be able to deduct a fair amount from that figure or add it to the price quoted by the power company.

A new piece of apparatus requiring power is suggested for the factory or engine room. Will it be a profitable investment with the high power cost that will have to be charged against it? Assuming that it will not overload the plant, the actual increase in operating expense will be only that of the additional coal required, perhaps half of the value obtained from the total cost of a horsepower. In estimating the cost of power for this machine it will be hardly fair to charge it at a lower rate than the rest of the plant, but the only actual increase in power cost is for the coal consumed, and anything above this will be distributed as a profit over the rest of the plant in the form of a decrease in the total cost of a horsepower.

There is another side to this question. In nearly every going concern the amount of power used shows a steady increase from year to year, and the time is not distant when there must be an addition to the power plant. The new machine does its share toward forcing an extension of the plant, even though it is not necessary to make the addition for several years, and should be taxed accordingly.

The conscientious engineer is always endeavoring to increase the efficiency of his plant and frequently it is necessary to spend more or less money to effect the improvement. Will it pay? This is generally answered

by the amount of coal that will be saved. If a horsepower will be saved, is not the engineer entitled to the same estimate that is made for the cost of a horsepower? If there is a saving of steam before it reaches the engine, should not all the overhead charges in connection with the generation of a pound of steam be included?

It is true that the only direct saving is in fuel, but he is also easing the load on the plant which may be the means of preventing a breakdown at some future date; he is also postponing the time when the plant must be enlarged. The fact that the amount of power involved in a single instance is small should in no way alter its treatment in this respect. True, 1 hp. more or less will never cause a breakdown or mean enlarging a plant, but "it is the last straw that breaks the camel's back." It must be remembered that this saving may be one of a hundred or more similar ones that arise in a few years.

Still another case that is treated unfairly by using the accredited value of a horsepower-hour is the installation of a machine using a large amount of power for short periods only, and with long intervals of rest. Such a machine may call for a large portion of the total plant capacity while in operation, but consume a comparatively few horsepower-hours during the month or year.

Assuming that fuel constitutes one-half the value of a horsepower, it would not be unjust to charge the machine in question with one-half the amount that it would require for continuous operation and to add to that the amount of fuel it actually requires, or, what is the same thing, add its horsepower-hours charged at half the usual rate. This method would be too severe, especially if the machine carried its load for short periods only, but a higher charge should be made than for a machine that is in continuous operation.

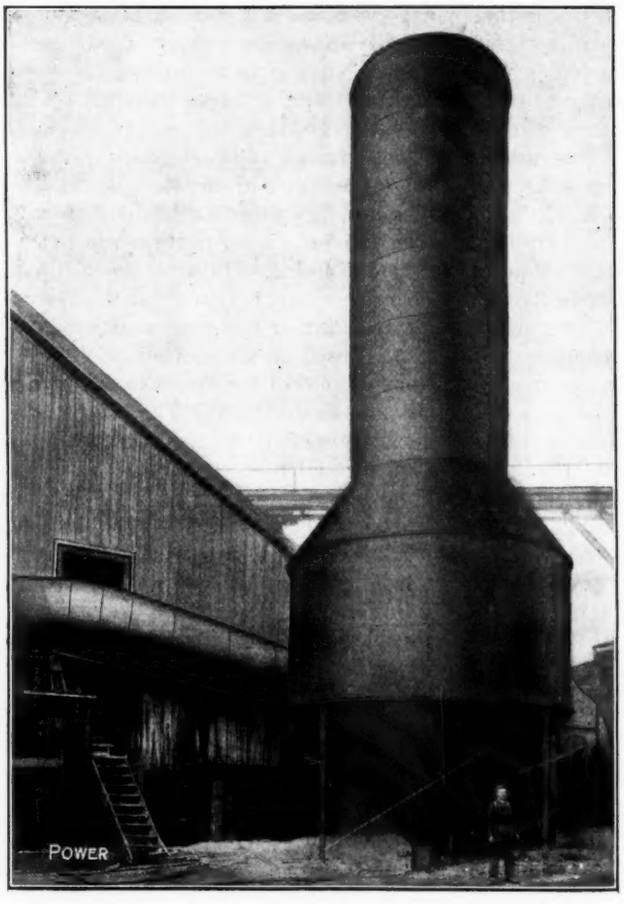
Power companies fully realize the justice of such a system of charging and establish their rates accordingly at the risk of dissatisfied customers and interference by legislation or public-service commissions. Their customers are provided with a maximum demand meter, which records the maximum number of kilowatt-hours used during a short period (fifteen minutes) during the month. Two customers may use the same number of kilowatt-hours recorded by the ordinary meter during the month, but one will show twice the maximum demand of the other; the one with the higher demand will be charged at a higher rate than the other. Such a system is not entirely fair for all cases, for the customer showing the high demand may have been using that amount for several hours each day during the time of maximum load on the station and running comparatively light for the rest of the time, which would be hard on the station and deserve a high charge.

Then, again, he may have been running a fairly constant load for one-half of the month and have shut down the other half, which would not be so bad; or he may have been running for the entire month at practically the same rate as the customer with half the maximum demand reading, but have used power at the higher rate on a single occasion for 15 minutes only and during a rather light load on the station, in which case it would be hardly fair to increase his rate. It is practically impossible to obtain exact data as to how the customer uses power and to charge accordingly, but the system referred to is likely to be fair in the majority of cases and is an incentive to the customer to avoid throwing on excessive loads for short periods. The fixed charge per kilowatt-hour, which makes the customers who use power at a fairly uniform rate stand a portion of the cost of supplying those who carry their load for short intervals only, is certainly unfair to the former. It is equally unfair to charge machines that operate continuously with a part of the cost of furnishing power for the one that operates infrequently.

Mechanical Draft Installation Collects Cinders and Sparks

The Bloedel-Donovan Co., Bellingham, Wash., recently installed a successful induced-draft apparatus, the magnitude of which can be appreciated by comparing it to the man in the foreground.

This apparatus is designed to collect all sparks and cinders, and thus eliminate the fire risk. The cinders are



COLLECTOR AND MECHANICAL DRAFT FAN

caught in the collector and diverted into a flume of water, which empties into Puget Sound.

The apparatus also makes it possible to keep the lumber in the yards clean, and is used in connection with boilers burning shavings and sawmill refuse. At the time the photograph was taken, the boilers were delivering 2300 hp., which is greatly in excess of their normal rating. This increase in boiler capacity is due to the additional draft obtainable with the induced system.

Another advantage is that steam is kept constant at any desired pressure. When the pressure tends to decrease, the fan speeds up automatically and does not allow the pressure to drop. This enables the plant to respond to sudden demands for more steam.

The installation was made by the B. F. Sturtevant Co.

Tests of Substitutes for Gasoline*

By J. A. Moyer†

SYNOPSIS—Comparative tests of kerosene, alcohol, motor spirit and mixtures of kerosene and gasoline as substitutes for gasoline in engines; also the effect of water injection as determined for each of these cases and air injection for gasoline alone.

Generally speaking, gasoline is the only fuel used for automobiles in this country, while enormous quantities are required for farm tractors, as well as for stationary and marine engines of all types. The investigations herein described were conducted during the past year by the Engineering Experiment Station of the Pennsylvania State College to determine the applicability of kerosene, alcohol, motor spirit and mixtures of gasoline and kerosene as substitutes for gasoline in engines. Most important results, as regards the effect of the injection of water and air on the capacity and economy of the engines, were also obtained, and tests and experiments to determine the underlying reasons for the peculiar action of water when sprayed into the combustible mixture before it enters the cylinder, are being continued.

The consumption of gasoline for power purposes has increased enormously during the past few years, as the following table shows:

TABLE 1. CONSUMPTION OF GASOLINE IN THE UNITED STATES

Year	Bbls.
1910	5,375,000
1912	12,000,000 (124% increase over 1910)
1914 (estimated)	25,000,000 (366% increase over 1910)

A few years ago, this country supplied the world with gasoline, while in 1913 our exports were only one-fifth of the total required for the demand in foreign countries. If the home consumption continues in anything like the same rate, the United States will soon have no gasoline to export.

The enormous increase in the demand for gasoline is due to the great increase in the number of automobiles and auto trucks. In 1902 there were only 15,000; in 1912, more than 900,000 and in 1914 it is stated that one manufacturer alone will produce 300,000 automobiles. In the ten years from 1902 to 1912, for which period we have the most correct data, the number of vehicles using gasoline for motive power has increased sixty-fold, while the production of the grades of *crude petroleum* most suitable for making gasoline increased only 100 per cent.

Methods of Increasing the Production of Gasoline

Using Heavier Distillates—There is not now and never has been a definite standard of gravity test for the petroleum products. Gasoline as sold in commerce may have a specific gravity as high as 0.72, equivalent to 64 deg. Beaumé. In the early history of the oil industry, the lighter distillates of petroleum were considered dangerous and practically useless. Gasoline was then very cheap and the refiners were glad to find a market for it at any price. Under these circumstances naturally the production of gasoline would be limited as much as possible and only the lightest distillates, such as would vaporize and form an inflammable mixture at room temperatures, were sold under this classification. With the rapid development of gasoline engines, however, the conditions have so much changed that the refiner now seeks to make the production of gasoline from crude oil as large as possible and includes under this name a large part of the distillates which do not vaporize readily at ordinary temperatures.

Compressing Natural Gas—Another important process for making gasoline is that of compressing natural gas. In the natural-gas regions the gas is known as "wet" and "dry," depending on its condition as regards saturation with oil. What is known as "wet" gas is saturated with gasoline vapors or light hydrocarbons.** When the "wet" gas is subjected to high pressure and low temperature, the gasoline vapors are condensed and are readily separated from the gas. This product from the compression of natural gas is extremely light and of varying volatility and must usually be mixed with a heavier petroleum distillate to make a product approaching the gravity of commercial gasoline.

Cracking—Equally important is the method of converting heavy petroleum oils into gasoline by the method of "cracking" or dissociation, which consists essentially in breaking up, by the application of heat under favorable circumstances, the heavy petroleum products into lighter distillates of entirely different atomic proportions.

This method was first demonstrated by Thorpe and Young, in 1871, but was not developed commercially until about 1913, when the exceptionally high prices for gasoline spurred investigators to an unusual degree to find new processes to meet the demand. These early investigators showed that by applying heat to solid paraffin, it could be converted into the vapors of hydrocarbons (paraffin and olefines), which are liquid at ordinary temperatures. By the simultaneous application of both heat and pressure to solid paraffin in a closed retort, these liquid hydrocarbons can be separated and removed from the heavier constituents. In its commercial application, "cracking" consists in bringing a suitable heavy petroleum product together with a relatively small quantity of water into contact with a large surface of iron or steel in highly heated retorts, and as a result a considerable percentage of the heavy distillate, depending, of course, on its physical properties, is converted into gasoline.

Substitutes for Gasoline

Kerosene—By far the most important substitute for gasoline having any considerable advantage from the viewpoint of the engineer is the ordinary kerosene of commerce. During the past few years the production of kerosene in this country has been much larger than the demand, and, compared with gasoline, the price is, therefore, unusually low. The great commercial advantages which would result if kerosene could be satisfactorily sub-

*Complete data and results will be published later in Bulletin No. 7, of the Engineering Experiment Station, by J. A. Moyer and E. N. Bates.

†Professor of Mechanical Engineering in the Pennsylvania State College.

**Natural gas contains some methane (CH_4), pentane (C_5H_{12}), hexane (C_6H_{14}), etc., all of which are liquid at ordinary temperatures after they have been removed from the gas.

stituted for gasoline can be best appreciated when it is considered that the crude oils now used for supplying gasoline will supply kerosene up to 50 per cent. of their volume, while the gasoline production from these oils by distillation alone is seldom more than 8 to 10 per cent.

Kerosene has a slightly higher heat value than gasoline per unit of volume, as shown by Table 2.

TABLE 2. CALORIFIC VALUES FOR KEROSENE, GASOLINE AND ALCOHOL

Fuel	Sp.Gr.	B.t.u. per Lb.	B.t.u. per Gal.
Gasoline	0.72	20,462	122,770
Kerosene	0.80	19,890	132,700
Alcohol	0.836	8,875	61,800

Until our supplies of gasoline became limited, the principal demand for kerosene was for illumination, which demand is now diminishing. Fortunately, however, there has been a steadily increasing demand for kerosene for use in cooking and heating stoves, and also in the constantly increasing requirements for farm engines of both the stationary and tractor types.

In thickly populated districts the use of kerosene in engines is objectionable, on account of the difficulty in securing a clean and odorless exhaust by the use of the ordinary types of carburetors. Many motor vehicles are being operated without this difficulty with the exhaust by using a mixture of gasoline and half kerosene. Whenever kerosene is to be used alone for the operation of an engine a carburetor suited to this particular type of fuel must be used for successful operation.

When kerosene is used in automobiles, except under conditions of unusual carefulness, it is difficult to prevent the chassis and even the interior of the body from becoming unpleasantly odorous.

As regards storage, kerosene is much more satisfactory. Gasoline vaporizes readily at ordinary temperatures and there is considerable loss by vaporization from storage tanks; also this vapor increases the fire hazard. Kerosene, on the other hand, does not vaporize readily at ordinary temperatures, therefore is less dangerous and can be stored without much loss from vaporization.

Motor Spirit—This petroleum distillate is a low grade of gasoline, which is marketed at a lower price than gasoline. It has more color than gasoline and kerosene, having a decided yellowish tinge. Its specific gravity is 0.73, or about 63 degrees Beaumé.

Acohol—The denaturated alcohol used in these tests was of the kind obtainable commercially from large producers. The specific gravity was 0.836, equivalent to 37 degrees Beaumé and corresponding to 80 per cent. alcohol by volume, or 76.1 per cent. by weight. The lower heat value was 8875 B.t.u. per pound, and the price 45c. per gallon in barrel lots.

Alcohol can be used successfully in any engine adapted to the use of light petroleum products. Engines designed primarily for using gasoline will run satisfactorily with normal compression when operated with alcohol fed through almost any of the good commercial types of carburetors. However, it is usually just as difficult to start an engine with alcohol as with kerosene; hence it is desirable to start with gasoline to heat up the engine and then open the connection to the alcohol tank.

As long as the price per gallon of alcohol is not considerably lower than gasoline, it cannot come into general use for power purposes. The tests, which will be described later, show that the efficiency of the engine is about the same for alcohol and gasoline,†† and Table 2 shows that the heat resulting from combustion is (in B.t.u. per gallon) about 61,800 for alcohol and 122,700 for gasoline. There is, therefore, about twice as much power available from a gallon of gasoline as from the same measure of alcohol.

Comparison of Fuels with and without Water Injection

The tests recorded here were made on a four-stroke-cycle stationary type of water-cooled engine, designed particularly for operation with gasoline. The cylinder bore was 6¾ in. by 10-in. stroke, and governing was by the "hit-and-miss" method. The primary object was to determine the maximum power and fuel consumption for each of the fuels used; first, without injecting water into the fuel-intake pipe and, later, with water injection. It is well known that the injection of water is effective in preventing so-called preignition, especially with fuels like kerosene, which is prone to produce excessive "pounding" in the cylinder when running under heavy load. It has been contended that the water injected with the fuel would, since it becomes superheated steam, have a beneficial effect, both as regards the maximum power obtained and the fuel consumption. The tests showed that the maximum horsepower of the engine is considerably increased, especially when kerosene is used for fuel; but in all cases with a sacrifice of economy; that is, the fuel consumption per horsepower-hour is considerably greater with water injection.

These tests were made with a carburetor, in which the fuel was discharged under pressure in a fine vapor from a special spraying device. The carburetor was effectively heated with the exhaust gases, and after the engine was once heated uniformly, its operation was very little affected by varying the amount of heating of the mixture within the carburetor. The amount of water injected was regulated by hand with a needle valve; in every case just enough being injected to prevent unusual pounding. Ignition timing in this series was practically the same for all tests.

Kerosene—The following data are the results of tests made under these conditions when using kerosene for fuel.

TABLE 3. KEROSENE (SP. GR. = 0.80) WITH WATER INJECTION

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injected, Per Cent.***	Fuel Cost per B.Hp.-Hr., Cents
1	6.03	1.33	71.5	1.80
2	8.05	1.20	75.8	1.62
3	8.11	1.19	70.4	1.61
4	8.97	1.12	33.3	1.51
5	10.99	1.09	48.9	1.47
6	11.09	....	122.0	.....

***Percentage by weight of fuel used. The price of the kerosene was 9 cents per gallon in both cases.

TABLE 4. KEROSENE (SP. GR. = 0.80) WITHOUT WATER INJECTION

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injected, Per Cent	Fuel Cost per B.Hp.-Hr., Cents
7	3.67	1.328	0	1.79
8	6.05	1.250	0	1.69
9	8.36	1.053	0	1.43

Fig. 1 shows graphically the results given in Tables 3 and 4. It will be observed that the maximum power of the engine was increased from 8.36 horsepower, which was

††This holds true when the same degree of compression is used for both gasoline and alcohol. However, with alcohol it is possible to employ much higher compression, in which case a higher thermal efficiency is obtained; see Bulletin 43, Bureau of Mines.—Editor.

the safe limit without water injection, to 11.09 horsepower with water injection. For all powers, however, the amount of fuel used was greater when there was water injection and consequently the cost per unit of power was also greater. Obviously, it is most desirable, therefore, to cut off the supply of injection water entirely at light loads, and carburetors designed for injecting water automatically into the combustible mixture should be arranged to cut off the supply of water automatically at light loads. Test 6 is added to Table 3, merely to show that the engine operated satisfactorily even when the weight of water injected was 22 per cent. greater than the kerosene.

Mixture of Kerosene and Gasoline

Another set of tests was made using a mixture of half gasoline and half kerosene by volume. The price of the kerosene was 9c. and the gasoline 18c. per gallon.

TABLE 5. KEROSENE AND GASOLINE (HALF AND HALF BY VOLUME) WITH WATER INJECTION

Sp. Gr. of Kerosene, 0.80; Sp. Gr. of Gasoline, 0.72

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injected, Per Cent.	Fuel Cost per B.Hp.-Hr., Cents
10	4.07	1.250	9.0	2.67
11	7.99	0.974	22.9	2.07
12	8.02	1.050	67.5	2.24
13	8.04	0.992	40.2	2.12
14	10.70	0.845	99.5	1.80
15	10.88	0.820	82.3	1.75
16	10.90	0.923	76.3	1.97

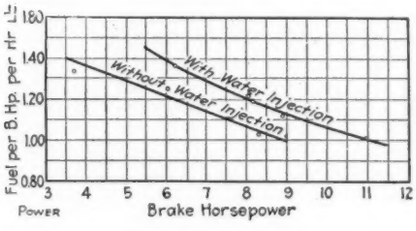


FIG. 1. KEROSENE WITH AND WITHOUT WATER INJECTION

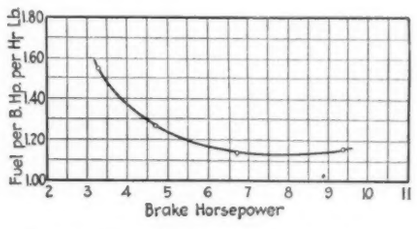


FIG. 2. FUEL CONSUMPTION VS. BRAKE HORSEPOWER WITH ALCOHOL

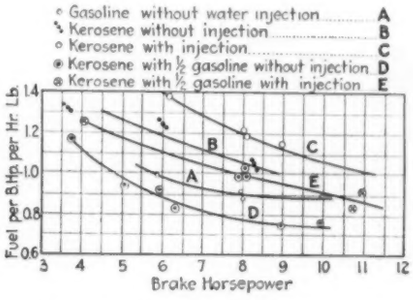

Gasoline without water injection A
Kerosene without injection B
Kerosene with injection C
Kerosene with ½ gasoline without injection D
Kerosene with ½ gasoline with injection E
Fuel per B.Hp. per Hr. Lb.
Brake Horsepower

FIG. 3. ECONOMY CURVES FOR DIFFERENT FUELS TESTED

TABLE 6. KEROSENE AND GASOLINE (HALF AND HALF BY VOLUME) WITHOUT WATER INJECTION

Sp. Gr. of Kerosene, 0.80; Sp. Gr. of Gasoline, 0.72.

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injected, Per Cent.	Fuel Cost per B.Hp.-Hr., Cents
17	2.64	2.50	0	5.33
18	3.72	1.17	0	2.50
19	5.12	0.94	0	2.02
20	5.98	0.92	0	1.97
21	8.23	0.82	0	1.67
22	8.92	0.74	0	1.58
23	9.92	0.76	0	1.62

Motor Spirit

A few tests were made, using the same engine and the experimental carburetor, with motor spirit. The results, as shown in Table 7, indicate also that with this fuel water injection is detrimental to economy.

TABLE 7. MOTOR SPIRIT, WITH AND WITHOUT WATER INJECTION

Sp. Gr. 0.73

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injected, Per Cent.	Fuel Cost per B.Hp.-Hr., Cents
24	7.93	0.80	60.1	2.12
25	7.93	0.84	59.9	2.22
26	7.93	0.78	0	2.05

Price of motor spirit, 16 cents per gallon.

Gasoline

For the purpose of comparison, tests similar to those given in the preceding table, were made with gasoline. No tests, however, were made with this fuel when water was injected into the cylinder, as the sort of "pounding" in the cylinder observable with the other fuels did not occur.

TABLE 8. GASOLINE, WITHOUT WATER INJECTION

Sp. Gr. 0.72

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injected, Per Cent.	Fuel Cost per B.Hp.-Hr., Cents
27	3.71	2.17	0	6.52
28	5.88	0.99	0	2.97
29	7.93	0.86	0	2.58
30	7.95	0.86	0	2.58
31	9.91	0.85	0	2.55

Price of gasoline, 18 cents per gallon.

Fig. 3 shows curves of fuel consumption plotted against brake horsepower for kerosene, the mixture of half kerosene and half gasoline and also gasoline alone, and shows clearly the effect of water injection in all cases.

Alcohol

Similar tests were made with gasoline, kerosene and alcohol in a high-speed experimental automobile engine with water-jacketed cylinders. The carburetor used was a Russian make and was designed especially for use with alcohol and kerosene. Brief data of these tests are given in Table 9.

TABLE 9. ALCOHOL WITH NORMAL COMPRESSION, WITHOUT WATER INJECTION

Sp. Gr. 0.836

No. of Test	Duration of Test, Min.	R.p.m.	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Fuel Cost per B.Hp.-Hr., Cents
32	60	533	3.22	1.56	10.70
33	60	585	4.63	1.29	8.92
34	30	725	6.66	1.12	7.80
35	30	1020	9.45	1.16	8.02

Price of denatured alcohol, 45 cents per gallon.

Two tests were also made with thirty-three and fifty per cent. water injection with the following results:

TABLE 10. ALCOHOL, WITH NORMAL COMPRESSION AND WATER INJECTION

Sp.Gr. 0.836

No. of Test	Duration of Test, Min.	R.p.m.	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Water Injection, Per Cent.	Fuel Cost per B.Hp.-Hr., Cents
36	30	766	5.65	1.43	33	9.87
37	30	641	4.73	1.66	50	11.45

Fig. 2 shows the fuel used without water injection per brake horsepower-hour at 5.65 horsepower to be 1.19 pounds, and according to Test No. 36, Table 10, the consumption for the same power with 33 per cent. water injection is 1.43 pounds. Similarly at 4.73 horsepower the fuel consumption from the curve is 1.29 pounds and from Test No. 37, 1.66 pounds. All the tests, therefore, indicate that there is a loss with water injection.

Tests with Air Injection

A four-cylinder, air-cooled automobile engine was tested with a commercial type of carburetor. The so-

called air-injection device is illustrated in wide-open position in Fig. 4, and consists of a central cylindrical valve with scalloped ports, controlled by the lever *A*. The valve is held down on its seat by the spiral spring. Small movements of the valve from the closed position make relatively much smaller areas for the admission of the air than the same amount of movement when nearly wide open. The thread shown on the apparatus is to be screwed into the inlet manifold of the engine. The opening of the valve was varied in the tests recorded in Table 2, in which the engine was operated with gasoline.

TABLE 11. AUTOMOBILE ENGINE OPERATED ON GASOLINE, WITH AIR INJECTION

No. of Test	Brake Hp.	Fuel Used, Lb. per B.Hp.-Hr.	Opening of Air Injection Valve, In.
45	10.76	0.976	0
46	12.14	1.007	0
47	11.70	0.864	0.11
48	11.01	0.804	0.14
49	11.40	0.838	0.20

It will be observed from these data that the economy of the engine is considerably improved when air is "injected" into the manifold. Extreme care was taken to get the best possible adjustment of the carburetor before the air "injection" device was used. An intermediate position of the air valve gave the best results; that is, an opening of 0.14 in. gave lower fuel consumption than openings of 0.20 and 0.11 in.

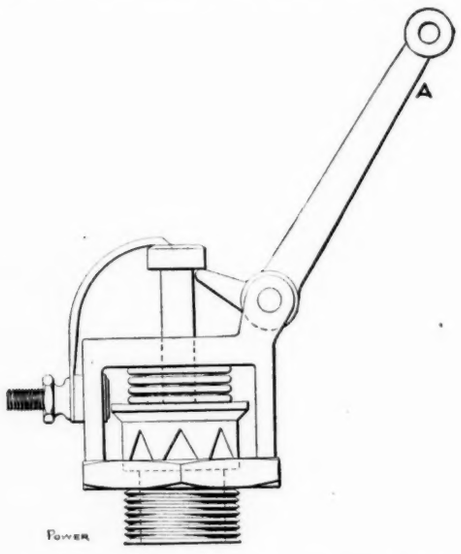


FIG. 4. SHOWING VALVE AND PORTHOLES WITH AIR VALVE OPEN

The same device has been tested on various types of carburetors on both air-cooled and water-cooled automobile and aeroplane engines, and in every case improvement in economy has been shown. For average road operation on automobiles where carburetors are set for relatively rich mixtures for a quick "get-away," such a device for making lean mixtures is serviceable and economical.

CAUSE OF PREIGNITION IN KEROSENE ENGINES

What has usually been called "preignition" in engines operating with kerosene and distinguished by a sharp pounding at the connecting-rod, is probably not preignition at all, as shown by many indicator diagrams taken on these engines when the pounding was severe. The explosion, which appears to be violent, does not occur until after the piston is started on the return stroke. This may be due to a "cracking" of the heavier portion of the kerosene, which, due to the lack of high temperature necessary to vaporize it, has been carried into the cylinder in minute drops and under the high temperature and high pressure of compression, breaks up into an explosive gas and a very heavy oil or even carbon.

Vacuum Heating without Thermostats

BY E. F. HENRY

"A vacuum system is an ordinary gravity return system with a college education," it was stated a few days ago. It causes speculation as to whether the college education is any more necessary to the gravity system than it is to some young men.

The large virtue of the vacuum system is that it enables more heat to be abstracted from the steam before it is thrown away than in the older systems. To do this it is necessary to make a condenser of the heating system so that only hot water will return to the vacuum pump. Provision is always made for injecting water into the return pipe, so that the pump will not attempt to pump steam, and so that the temperature of the return can be kept enough below the boiling point not to flash into steam in the pump cylinder and prevent the pump from working. All this is supposedly taken care of by the thermostatic valves on the return end of each radiator and coil.

Like all other thermostatic apparatus, some work better than others, but it has been found by operating engineers that if the thermostat will not work it can be removed, like a man's vermiform appendix—without great inconvenience to the patient. All that is necessary is a globe valve with the handle removed, so that each one can be adjusted to the requirements of its coil. Theory or no theory, it is found that the opening necessary to take care of a given coil is practically independent of the weather. If more heat is needed, increase the vacuum, and the returns will respond without changing the setting of the valves.

All the functions of the system are preserved, it acts as a condenser and nothing but hot water comes back, provided no change is made in setting the valves. Of course, a half-inch valve wide open will let steam out of a radiator, unless it is a pretty big one, but that is no more likely to happen than for a thermostat to go wrong, possibly not quite as much so.

Stripped of the thermostat, the vacuum system becomes as simple a proposition to install as a gravity return that discharges into a tank from which boiler-feed water is taken, plus the advantage that the vacuum will take care of a great many little traps in the piping that come about, not always through faulty construction, but because of pipes getting bent or pipe hooks coming out, and so on.

The difference in cost of water consumed, the cost of heating feed water and the greater range of temperature in the radiators, would make changing over an old plant to a vacuum system almost always a paying proposition, particularly if the man in charge of the power plant has nerve and confidence enough to tackle the job without a high-priced engineer to lay it out.

Editorials

"Pass It On"--To Whom?

In an editorial in the Mar. 24 issue, we called attention to the many trade publications, magazines, etc., that are skimmed over if looked at at all, tossed aside to be read "some day," relegated to the waste pile in the back room, or sent at once to the furnace room without seeing if they may not contain articles or advertisements of present financial value. If such shall be their fate, they are an expense and a nuisance.

But the day of large wastes is nearly at an end. What may be waste product to one man is raw, necessary and valuable material to the next man. The question therefore is, "Who is the next man in your organization who should look over your waste product and get good value therefrom?"

It is being answered differently in large engineering works. In these works a clerk takes charge of the periodicals, magazines, professional papers, and trade catalogs pertaining to their industry, and sees that they are temptingly displayed in the reading room of the office building, to be read during the noon hour or taken home at night to be read with more care.

This is admirable for the office force, the salesmen, clerks, and others who may have the time and want to accept the opportunity. But what about the men in the works, the superintendents, foremen, chemists, engineers and other specialists? Might not one of those papers give him just the idea, to get that for which the company has been spending perhaps thousands of dollars in experimentation? Would not the knowledge that a new machine has been put on the market or that a new process has been devised, the use of which may halve the cost of production of some part, cause further inquiry to be made and the possible saving to be effected? Might not these new savings, even if made only occasionally, pay well for the cost of some system that will keep the organization well informed on subjects pertaining to the company's output and system of manufacture?

System has now touched many lines of industry, but only occasionally do we find that it regulates the disposal of incoming printed matter. Why not, as other goods are treated, send it to the receiving room, route it to its proper department, even list it in the inventory, and hold someone responsible for it until it has been used in the routine work of the shop, factory, or plant?

To further conserve time, let each piece of printed matter such as catalogs, technical and professional papers, and the like, be entitled in ink with its general character, if its title is not fully explanatory. Then rubber-stamp in the margin of the title cover the names or initials of each of those men who may be held responsible for having read certain of the articles. Some technically trained person should act as routing clerk, read the titles of the articles, skim their contents, decide as to the real subject matter of each article and of its value to the organization, mark the page number of those articles that he thinks certain men should read opposite their name or initials on the margin of the cover, and send it to them in sequence. Those assigned an article should promptly read it with such care, make such notes, and take such further action, as they may think wise for the good of the company, sign their initials and the date on the line with their name on the assignment stamping, and forward it automatically by interworks mail to the next one on the assignment, and so back to the routing clerk for filing.

A still further refinement of this system is that of having weekly meetings at which certain ones will be expected to tell what they have read, since they last reported, which they consider of greatest value to the organization. This meeting may be held during or just after the noon hour, or in the evening if such seems desirable and necessary.

For the advancement of your men and your business, after you have read a trade paper or a technical article in a professional journal, *pass it on* to those of your employees who are most interested, and do not waste these "goods receivable."

Companions--Prosperity and Power

On October the fourth the European catastrophe had endured two months. Considering the gigantic proportions in men and area immediately affected, and realizing that those engaged are world powers in business as well as armament, there is little wonder that industry the world over should suffer; that banking restrictions should exist, and that securities be more or less demoralized.

For Europe the outlook is dark. The business which the belligerents did with one another has ceased and just how soon after the conflict it will be resumed and how completely, one can only conjecture at this time.

Within recent years, Germany has become a nation of importance in the manufacture of engineering materials. These amounted to approximately twenty-billion dollars annually. Of the total export trade in electrical equipment, nearly thirty-five per cent. went to those with whom she is now at war, the rest was distributed through the United States, South America, Africa and the Orient. Coal costs considerable in South America, and to furnish power to her growing industries her water-power resources are being developed, calling for an ever-increasing importation of electrical and power equipment, particularly by Brazil, Argentine and Chile. Heretofore, Germany has exported the largest share of this class of equipment to Argentina and was a strong competitor throughout South America, whose total imports in electrical machinery and supplies amount to more than twenty millions. These countries have always been heavy consumers of European coal, and this is another good field for American industry.

Steel is an excellent barometer by which to judge econ-

omic conditions. We read that large orders from abroad for steel and machinery have already been placed and more are awaiting adjustments. Also, commercial reports announce large orders for various goods placed here and there by foreign business houses, orders which do not excite wonder by their magnitude but greatly encourage because they are for goods for people who heretofore have bought elsewhere.

It remains then to shoulder the responsibility thrust on us at a time when the belligerents are too grossly engaged in battle to properly attend to their business possibilities, and to make the quality of our goods, the facility of our service and the character of our exchange such that our new buyers will stay with us to an extent great enough to pay for going after their business.

American industry has received an unprecedented impetus. Availability of power and equipment for its application always have, and must in this instance, precede the growth of industry. Resumed activity of industries has a like effect on power plants and allied industries for prosperity and power are inseparable and interdependent companions.

Percentage of Vacuum

What is meant when a condenser manufacturer guarantees to produce a vacuum within a given percentage "of the possible"?

The natural inference would be that the vacuum should be the given percentage of that indicated by the barometer. If the barometer were, for example, 29 inches and the vacuum was to be 95 per cent. of the possible, one would suppose that the condenser must produce a vacuum of $0.95 \times 29 = 27.55$ inches. But in no condenser can the absolute pressure be less than that due to the temperature of the water vapor present. If air is present, the absolute pressure will be the sum of the pressures of the air and the water vapor.

It is the function of the condenser to get the condensate as cool as practicable and to remove the air as quickly as possible. The first requires a large condenser with plenty of injection or circulating water, the second, large air-pump capacity; but no matter how much condenser and air pump the manufacturer may furnish, he can never reduce the absolute pressure to less than that due to the temperature of the condensate. Furthermore, no matter how much water is used, the temperature of the condensate can never be quite reduced to the temperature of the condensing water. This sets a limit to the possibilities and makes possible another interpretation of a guarantee in terms of "per cent. of the possible."

To make the observation concrete, suppose a barometer of 29.8 inches; condensing water of 70 degrees; vacuum obtained 28 inches.

The vacuum obtained is $28 \div 29.8 = 93.96$ per cent. of the barometer.

But even with a high-vacuum water-jet pump it is impossible to get the temperature in the condenser less than 70 degrees, and at this temperature water vapor having a pressure of 0.739 inch will be generated. The best vacuum theoretically possible is therefore $29.8 - 0.739 = 29.061$ inches, and the 28 inches produced by the condenser is 96.35 per cent. of this possible.

If, however, the best possible vacuum is to be computed thus from the temperature of the condensate, the maker might furnish an inadequate condenser which would run warm and produce a poor vacuum; but this poor vacuum would still be a high percentage of that attainable at the high temperature. For instance, a condenser cools its condensate to 110 degrees and produces a vacuum of 26 inches with a 30-inch barometer. The vacuum corresponding to 110 degrees, where water vapor is involved, is 27.4 inches, of which 26 inches is 95 per cent.

It is well, therefore, to specify as the vacuum to be produced a given percentage of the barometric pressure; but if " the possible" as determined by the condensing water temperature is meant it should be so defined that there can be no ambiguity about it nor dispute about its interpretation.

The Cost of Power

What is the best means to determine the cost of power per kilowatt-hour or horsepower per year? The answers may be as many as there are engineers. It is quite easy to determine the cost to the satisfaction of the accounting department, but it is difficult to so assign the charges that the engineer will consider them equitable and the accounting department tolerate the numerous items involved in the system of account keeping.

The equitable distribution of charges will probably be argued by engineers for a long time, as the subject is of so much interest and a thorough knowledge of it so valuable in defending the engineer's administration in any plant. Just how far one should carry the subdivision of charges is limited by his desire to work up, enter and file the data. The chief consideration, however, should be this: How valuable are the data collected? Just as there are plants suffering from scarcity of data of their performance, so, too, are there others burdened with an excess of it. But one can hardly convince the engineers of these latter plants that they are overburdened.

The article, "The Cost of Power," on page 567 of this issue, analyzes and considers many phases of power-plant accounting, and should bring forth some good discussion.

Soon the refrigeration plant will be cut out or the load greatly reduced. Of course, you are preparing to thoroughly inspect and overhaul the system?

Those performance curves of the Marion Station for 1913 in the Oct. 6 issue have undoubtedly convinced many that this means of record keeping is one hundred per cent. useful.

Let's see, was there not a test conducted in New York City's Hall of Records? We have waited so long for the report to become public that we almost forgot the thing.

The contractor stood before him and with loud voice and wild gesticulations guaranteed to furnish for an indefinite period a coal that would not smoke, that was free burning, whose ash would not clinker nor fuse at any conceivable temperature; that would always have less than one per cent. moisture, and whose heating value was fifteen thousand heat units for every pound. Eagerly he bent forward to sign the contract, and then—he awoke.

Correspondence

Crankpin-Bearing Record

We have a crankpin box which has been in service for the last 15 years, running 10 hours a day at 215 r.p.m., and is still doing good work. It is a brass box with the button form of babbitt. The engine cylinder has been bored out twice during the life of these brasses. I believe this is an unusual record of service for a crank bearing of any material.

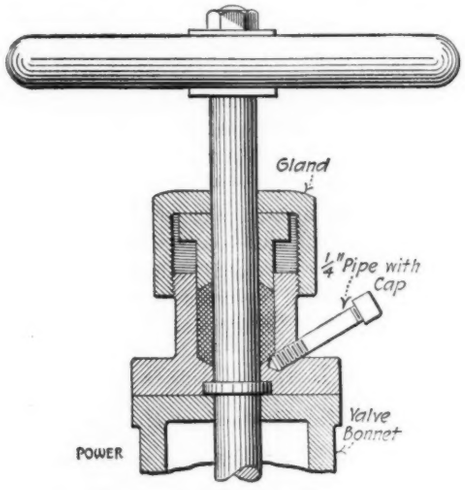
ALBERT WARNER.

Appleton, Wis.

Valves Packed under Pressure

The illustration shows a makeshift method of doing what the valve manufacturers should do properly. All modern valves should be capable of being repacked under pressure when wide open or shut, and most manufacturers make that claim for their product. In practice, however, it is found that even though they are tight when new, they soon develop slight leaks past the sealing joint or collar and it is then almost impossible to repack them without cutting the line out.

To overcome this difficulty we drill and tap ours for a ¼-in. pipe and put in a short piece of pipe with a cap as



PACKING SPACE VENTED

shown. When repacking, we open the valve wide, remove the gland and old packing, take out the pipe plug and see that the hole in the stuffing-box is open. The packing can then be put in, the gland brought down on it and the plug replaced without difficulty, any leakage during the operation escaping through the hole instead of blowing out the packing.

We have thirty or forty valves so fitted and have had no trouble in repacking them during the three or four years they have been in use. Every valve salesman claims that his valves do not need it. A very trifling increase in the cost of manufacture would save much trouble.

For packing high-pressure steam and hot-water valves, we have found the metallic packings, of which there are several on the market, much more satisfactory than fibrous packings.

JOHN C. WHITE.

Madison, Wis.

Cost of Operating a Vacuum Ash-Handling System*

In Mr. Ricker's letter in the issue of Sept. 15, under this title, there appears to be a confusion of the principal subject, the steam-jet operated system, of my letter in the July 7 issue, in the blower-operated system referred to in a later paragraph.

The figures I used to arrive at, 27.10 cents as the cost of handling a ton of ashes, were based on a tentative plant of a size and type suggested by the illustration in the Apr. 7 issue, hence the omission of a motor and exhauster. The cost of installation ($1800) was assumed from a desire to give the system all possible credit. The blower system, with which the cost of handling a ton of ashes amounted to 26 cents exclusive of overhead charge, served ten boilers and handled about 35 tons of ashes per day. This layout had some 300 ft. of ash pipe with three right-angle bends, which explains the large power requirement.

The costs of operation in the plants cited by Mr. Ricker are interesting and tend to prove the economy of the vacuum system of ash removal. The plant handling 40 to 50 tons per day with an annual repair cost of only $50 is particularly interesting—$50 a year would barely provide wheelbarrows in a plant handling ashes by that means and of the capacity stated.

C. O. SANDSTROM.

Kansas City, Mo.

Hocking Valley Slack Coal

In the May 26 number of POWER, the writer endeavored to show graphically the relationship which exists between the heat value and ash content of Hocking Valley slack coal, basing same upon the values obtained in testing something like 1800 samples of the coal in question, many of which were average monthly samples, and each of which represented 30 or more daily samples. Since that time this number has been raised to approximately 5000 samples.

As stated in the original article, all the tests were made with the highest type of apparatus for such work and by men thoroughly experienced in the work, under the supervision of the writer.

In addition to this, the laboratory has been checked many times by other laboratories using similar apparatus and to date has not been obliged to retract any figures on coal testing. In other words, the practice of this laboratory follows the general run of coal testing as advised by the Bureau of Mines and the American Society

*See Apr. 7, July 7, Sept. 8, Sept. 15, 1914 issues.

for Testing Materials with one or two important exceptions only.

In the June 30 number of POWER, there appeared a criticism of the curve as published by the writer by E. R. Andrix, of Columbus, Ohio, who is of the opinion that the heat values are higher than warranted by his tests for the given ash contents. He refers to the Ohio State Geological Survey's Bulletin of 1908 as a reference authority to back up his opinion.

We are pleased to learn his views and, to make it possible to get to the bottom of this matter, believe it is best to publish the data upon which the curve in question is based. If we are at fault in our methods or manipulation, we certainly desire to be corrected and we receive such criticism in the same kindly manner in which it is advanced. Criticism is the very life of laboratory work and should be given and received as an aid to correct results in any line of endeavor.

As mentioned above, we do not adhere to the methods of the Ohio Survey in two important factors, namely, the Fineness of the Samples and the Pressure of Oxygen used in the calorimeter. We do not believe that complete combustion is possible in the long run on the coal in question if the sample is ground to 60-mesh fineness, nor if only 18-20 atmospheres of oxygen are used. We base our claim on comparative tests made in 1912 in this laboratory which we now repeat as follows:

Pressure of Oxygen Essential to Completely Burn Hocking Valley Slack Coal in the Calorimeter

1. Average of 10 cars received, June 10, 1912, Hocking Valley Slack Coal:
   a. 20 atmospheres oxygen, 11,819 B.t.u., 12.03% ash.
   b. 25 atmospheres oxygen, 12,489 B.t.u., 12.03% ash.
   (a showed considerable unburned coal, b did not.)
2. Average of 9 cars received June 24, 1912, Hocking Valley Slack:
   a. 20 atmospheres oxygen, 11,510 B.t.u., 13.65% ash.
   b. 25 atmospheres oxygen, 12,222 B.t.u., 13.65% ash.
   (a showed unburned coal, b did not.)
3. Average of 10 cars received June 27, 1912, Hocking Valley Slack:
   a. 20 atmospheres oxygen, 12,128 B.t.u., 12.48% ash.
   b. 25 atmospheres oxygen, 12,595 B.t.u., 12.48% ash.
   (a showed unburned coal, b did not.)

All the above samples were ground to 100-mesh fineness.

Each B.t.u. figure given is the average of two determinations, the greatest variation in checks being 70 B.t.u.

All samples were dried at 105 deg. C., for one hour before testing.

Grinding of Samples for Calorimetric Tests

Each of the above named samples in their original form was ground to 20 mesh and halved. One-half was then ground to 60 mesh, the other half being ground to 100 mesh. The comparative behavior of the coal of two degrees of fineness was then noted in the calorimeter. Oxygen at a pressure of 25 atmospheres was used in each case.

4. Same sample as 1 above:
   a. 60-mesh sample, 12,098 B.t.u.
   b. 100-mesh sample, 12,441 B.t.u. Difference 343 B.t.u.
   (b checks 1 above within 48 B.t.u.)
5. Same sample as 2 above:
   a. 60-mesh sample, 12,008 B.t.u.
   b. 100-mesh sample, 12,297 B.t.u. Difference 289 B.t.u.
   (b checks No. 2 above within 75 B.t.u.)
6. Same sample as 3 above:
   a. 60-mesh sample, 12,233 B.t.u.
   b. 100-mesh sample, 12,560 B.t.u. Difference 327 B.t.u.
   (b checks No. 3 above within 35 B.t.u.)

The Effect of both Coarse Grinding and Low-Oxygen Pressure

7. Same sample as 1 above.
   a. 60-mesh, 20-atmosphere oxygen, 11,609 B.t.u.
   This is 880 B.t.u. lower than 1-b above and 832 B.t.u. lower than 4-b.
8. Same sample as 2 above:
   a. 60-mesh, 20-atmosphere oxygen, 11,280 B.t.u.
   This is 942 B.t.u. lower than 2-b and 1017 B.t.u. lower than 5-b above.
9. Same sample as 3 above:
   a. 60-mesh, 20-atmosphere oxygen, 11,888 B.t.u.
   This is 707 B.t.u. lower than 3-b above and 672 B.t.u. lower than 6-b above.

In view of the above experimental results, we did not feel justified in using 60-mesh samples nor in using less than 25 atmospheres pressure of oxygen in our calorimetric tests on this coal. We adopted the use of this pressure of oxygen as our standard and 80-100 mesh as standard fineness in our grinding. As a matter of fact, fully 95 per cent. of our samples will wholly pass a 100-mesh screen, the remainder showing from 5-10 per cent. of 80-mesh particles. We do not believe there is anything to be gained by briquetting the samples of Hocking Valley Slack for calorimetric work. With reasonable care in admitting the oxygen there is little danger of loss of sample before the ignition and we find that the loose sample ignites more completely than the briquetted sample under the same conditions. We use a special type of receptacle for the coal within the calorimeter which gives us a thin layer of coal into which the oxygen penetrates uniformly. These capsules are of as wide a diameter as the construction of the bomb will permit, are made with rounded corners and are shallow. We do not find it necessary to use an asbestos pad beneath the coal when testing Hocking Valley slack.

Data for Curve

Curve: B.t.u. per Ash Content in Hocking Valley Slack

The fact that our specifications called for coal running not less than 12,000 B.t.u. per lb. accounts for the predominance of data around 12,000 B.t.u. The general average heat value of this coal for a period of three years was 12,300 B.t.u. with an ash content of 13 per cent.

Since plotting the original curve many more tests have been made, a total of over 5000, all of which conform with the original curve within reasonable variations.

In figuring the average data, we grouped the tests according to per cent. of ash, the first group being those samples which showed from 7.00 to 7.50 per cent. ash, the second 7.6 to 8.00 per cent. ash, the third from 8.10 to 8.50 per cent ash, etc.

In figuring these averages for the given ranges of ash content, we have given the proper weight for each

sample according to the tonnage of coal which each sample represented. Thus 10 cars showing an average ash content of 12.50 per cent. received twice the weight or credit that 5 cars showing the same or different ash received.

DATA

Average Monthly Samples from Interurban Power Stations:

Average Monthly Samples from Interurban Power Stations

Cars Received	Ash %	B.t.u. per lb	Range of Ash Content, %
60	7.33	13,229	7.0 to 7.5
58	10.69	12,617	10.6 to 11.0
57	11.39	12,580	11.1 to 11.5
55	11.96	12,811	11.6 to 12.0
61	12.22	12,385	etc., etc.
59	12.90	12,361	
56	13.28	12,298	
60	13.73	12,240	
60	14.28	12,117	
60	14.82	12,082	
57	15.22	11,965	
59	15.63	11,935	
61	16.10	11,857	
63	16.79	11,752	
57	17.37	11,560	
49	17.92	11,654	Exception to the general run
53	18.60	11,441	
55	19.62	11,367	
60	20.73	11,033	
60	22.19	10,840	
68	23.50	10,560	

Daily Samples Received at Power Stations in Detroit

30	6.60	13,420	6.00 to 7.00
41	8.65	12,957	8.50 to 9.00
12	9.18	12,934	etc., etc.
43	9.25	12,902	
51	9.88	12,788	
63	9.94	12,825	
81	10.33	12,656	
112	10.78	12,627	
282	11.31	12,518	
391	11.85	12,493	
410	12.28	12,426	
488	12.80	12,357	
482	13.33	12,276	
567	13.78	12,180	
244	14.34	12,068	
260	14.78	12,038	
168	15.34	11,927	
164	15.76	11,826	
99	16.38	11,737	
77	16.74	11,722	
29	17.37	11,607	
42	17.79	11,573	
13	18.23	11,434	
10	19.28	11,054	
9	19.96	11,097	Exception
9	20.18	11,257	Exception
5	20.82	11,051	
2	24.84	10,437	
2	25.17	10,320	

The above coal was shipped from about twenty different mines located in Athens, Perry and Hocking Counties, Ohio, and is, in this section at least, known as Hocking Valley Slack. The curve therefore represents the relation between heat value and ash on this composite range of slack coal, not coal from a single mine. For this very reason we believe our figures give the general run of this coal.

If it is desirable to correct the B.t.u. figures for the moisture contained in the coal as received it is necessary to deduct in proportion to the average moisture, namely, 9.85 per cent. All the above B.t.u. figures are on the samples after drying at 105 deg. C. for a period of one hour.

We desire to emphasize the fact that we have standardized upon our calorimetric methods only after thorough study of the coal being used. For coals of another type, it is possible that other degrees of fineness and other oxygen pressures might prove of advantage. For Hocking Valley slack coal, such as we received, we believe our methods are right inasmuch as we certainly get concordant results in our work and in check work with other laboratories in this section.

However, as stated above, we welcome criticism and will be pleased to give further data, etc., and to receive in turn the opinions of others backed of course by experimental and other evidence.

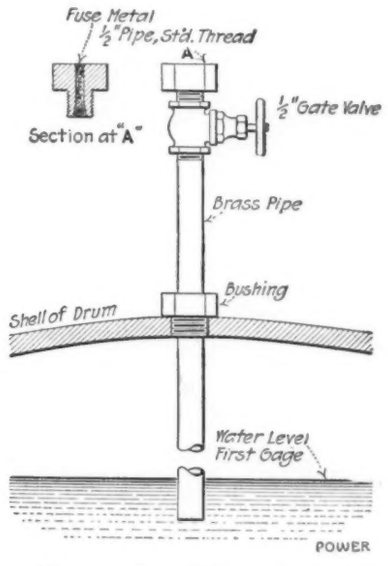
Finally, it may be well to state here the fact that while using Hocking Valley slack coal at the seven power stations of this company we burned an average of 670 tons per each 24 hours over a period exceeding 3 years, another point tending to back up our notion of the relationship in question shown by this coal.

MORGAN B. SMITH,
Ch. Chem. and Combustion Engr., Detroit United Lines.
Detroit, Mich.

Fusible Plugs

I read with interest your editorial of Aug. 25 on fusible plugs, as I have been working on this problem lately. In many plants they are a menace; scarcely less than inoperative safety valves, because of the unjustifiable dependence placed on them. In a certain plant containing ten 300-hp. Stirling boilers, one was burned three times, and finally nearly exploded. After each burning the fusible plug was removed and thoroughly cleaned.

An idea may be formed of how hot the boiler must



FUSIBLE LOW-WATER ALARM

have been, without melting the outside alarm type of plug, when the ebonite gasket between the nozzle and nonreturn valve was burned out. I wired the fusible disk to the bulb of a high-temperature thermometer and held both before a blow-torch flame and heated them very slowly to 480 deg. F. before the metal began to soften; at 500 it melted enough to drop out. The plugs in the other boilers were tried and found to be practically the same, except one which melted at 370 deg.

Even if the metal had fused it is doubtful whether any great amount of steam would have escaped on account of the many devices fastened to the pipe, including a whistle which had been given several coats of black paint, completely closing the steam orifice. The old alarms were taken out, and ones adopted as shown in the sketch. When the fusible plug blows out it makes a report like a pistol shot and the roar of the steam can

be heard all over the power plant. The fusible cones to fit in the plug *A* are tested before using by touching a bare high-pressure steam pipe with them. If they do not start to fuse in a contact lasting three seconds, they are condemned and not used.

Each month when the boilers are washed and cleaned the boiler washer removes the plug and takes it to the engineer who inspects and replaces it just before steam is raised after passing a ⅜-in. round rod down through the pipe and valve into the drum to make sure the passage is clear.

The watch engineer must state in his daily log the condition of the fusible plug when received by him, and he is held directly responsible for its condition. The gate valve is locked open with a padlock and chain and only the watch engineer has a key.

Five plugs have been blown out since Apr. 1, two from no apparent cause; and the others from a burst tube, a break in the pipe above the water line, and from low water.

S. H. Farnsworth.

Chicago, Ill.

Experience with Graphite

The water in this locality contains much carbonate and sulphate of lime, thus causing a great deal of pitting and corroding in the drums and tubes of our water-tube boilers, and heavy scale causing many overheated tubes.

We have overcome our difficulties by installing two large settling tanks, treating the water with the proper amount of soda ash and lime and giving the tubes a

Graphite Feeder

thorough cleaning with a mechanical cleaner, following it up with regular graphite treatment. The pitting and corrosion have stopped, no new scale is being formed, and two boilers are doing the work of the former three.

Feeding graphite into the suction of the boiler-feed pump as shown in the illustration, is advantageous because the graphite in passing through the pump prevents scale from forming on the valves and sleeves of the pump.

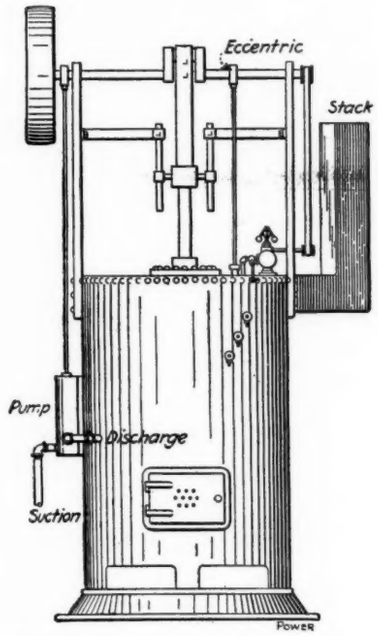
George Collister.

Salem, Kan.

Self-Contained Steam Plant

Much has been published recently about the unit plant of the locomobile.

Recently, I had occasion to look over some old machinery that had been in storage some thirty or more years



Self-Contained Steam Plant

and I unearthed a self-contained plant that showed that someone had the right idea years ago. One of the caretakers informed me that this particular device had been there for 35 years, so it's a sure old-timer.

The accompanying sketch gives an idea of the general construction of the unit. The boiler is of the vertical fire-tube type. Upon its top are two standards, riveted to the shell, which support the guides and crankshaft of the engine. On one end of the shaft is a flywheel 30 in. in diameter, and 5-in. face. Set into the top of the boiler is the cylinder and valve chest of the engine, the steam pipe coming up through the head, and turning into the valve chest as shown. The steam is controlled by a throttle governor on the steam line. The exhaust passes into the smoke-stack which is taken from the top side of the boiler. To the side of the boiler is attached a pump, driven from the engine shaft by an eccentric.

While the whole is rough in construction, and in its best day probably was not able to generate over 30 hp., yet it must have been a wonder for economy at that time.

Perhaps some of the old veterans can give some interesting details about this type of steam unit.

Arthur D. Palmer.

Dorchester, Mass.

[This type of power plant was built during the years of 1870 to 1877 and was developed by William Baxter, and manufactured by the Colts Fire Arms Co., Hartford, Conn.—Editor.]

Inquiries of General Interest

The Centennial Boiler Horsepower—When and by whom was the rule first adopted for rating the evaporative horsepower of boilers on the basis of 30 lb. of water per hour raised from water fed at 100 deg. F., and evaporated into steam at 70 lb. gage pressure?

A. A. B.

The first public adoption of the unit was by the committee of judges of the Centennial Exposition, 1876, in reporting the trials of competing boilers at that exhibition, the conditions being considered by them to represent fairly average practice of that period.

Scoring on Only One Side of a Crankpin—What are the causes of a scored crankpin when only one-half of the pin is scored?

H. A. C.

Scoring or cutting may be due to disintegration of the pin or the brasses from excessive pressure per square inch or want of proper lubrication, or from dirt finding its way to the bearing surfaces. Pressure is delivered from the connecting-rod upon the same side of the crankpin at each stroke of the engine and consequently the wear and cutting will be mainly on one side of the crankpin.

Relative Loss of Head in 3-In. and 4-In. Pipe Lines—What would be the relative loss of head pumping water through a 3-in. pipe line and pumping at the same rate through a 4-in. line of the same length?

J. G. B.

For discharging the same quantity of water in a given time through pipe lines of the same length and roughness of surface, the relative loss of head from friction will be about inversely as the fifth powers of the pipe diameters; hence, the loss of head with a 3-in. pipe will be to that with a 4-in. pipe as

$$\frac{1}{(3)^5} \text{ to } \frac{1}{(4)^5}$$

or

$$\frac{1}{243} \text{ to } \frac{1}{1024}$$

i.e., using a 3-in. pipe the loss will be

$$\frac{\frac{1}{243}}{\frac{1}{1024}} \text{ or } 4.17$$

times the loss using a 4-in. pipe.

Pressure Realized by Siphoning—What would be the pressure head, in feet, in the foot of the long branch of a water siphon 60 ft. below the highest point of the siphon which is 8 ft. above the level of the water that is siphoned?

M. J. K.

Neglecting pipe friction and having both branches of the siphon completely filled with water, the absolute pressure in the foot of the longer branch would be that due to 60 ft., plus the absolute pressure in the top of the siphon. As the pressure in the top of the siphon would be the pressure of the atmosphere less the pressure due to 8-ft. head in the shorter branch of the siphon, then the absolute pressure in the foot of the long branch would be the pressure head of 60 ft. plus the pressure of the atmosphere, minus the pressure head of 8 ft., i.e., the net pressure head above atmospheric pressure would be 60 — 8 = 52 ft.

When the siphon is in operation some of the atmospheric pressure employed in raising the water in the shorter branch and some of the pressure head due to the height of the longer branch would be employed in overcoming pipe friction. Hence, the effective pressure head would be reduced below 52 ft. by an amount which would be practically the same as the loss of head for the same velocity of flow through a horizontal pipe of the same roughness, size and length as the total length of the siphon.

Steam Required for Pipe Coils—How many pounds of steam per hour at 150-lb. gage pressure would have to be supplied to pipe coils containing 5000 lin.ft. of 1¼-in. pipe, the steam being admitted to the coils reduced to atmospheric pressure and discharged as condensate at that pressure, assuming the rate of transmission from the coils to the surrounding air to be 1.7 B.t.u. per hour per square foot of pipe surface per degree of difference of temperature; the surrounding atmosphere being at 70 deg F.?

R. L. Y.

A pound of steam at 100-lb. gage pressure, or about 115 lb. absolute contains 1188.8 B.t.u. above 32 deg. F. Admitted to the coils reduced to atmospheric pressure it would be superheated about 80 deg., i.e., its temperature upon admission would be 212 + 80 = 292 deg. F., and it would be fair to assume that the average temperature within the coils would be 212 + 40 or 252 deg. F. Discharged as condensate at atmospheric pressure, each pound of condensate would contain 212 — 32 = 180 B.t.u. above 32 deg. F. Therefore, each pound of steam introduced at 100-lb. gage pressure would part with 1188.8 — 180 = 1008.8 B.tu. As 2.301 lin.ft. of 1¼-in. pipe are required for 1 sq.ft. of external surface, and the average difference of temperature inside and outside of the coils would be 252 — 70 or 182 deg F., then, with a transmission factor of 1.7 B.t.u. there would be:

$$\frac{5000}{2.301} \times (182 \times 1.7) = 672{,}316+ \text{ B.t.u. required per hour.}$$

As there would be 1008.8 B.t.u. received from each pound of steam the coils, would require, per hour

$$\frac{672{,}316}{1008.8} = 666.45 \text{ lb.}$$

of steam at 100-lb. pressure.

Horsepower of Boiler—What would be the horsepower of a return-tubular boiler 44 in. diameter, 30 ft. long, containing 23 tubes 4 in. diameter by 20 ft. long?

F. J. R.

The commercial rating of a horizontal return-tubular boiler is according to the number of square feet of heating surface, allowing 10 sq.ft. per boiler-horsepower, assuming the heating surface to consist of:

(a) The surface of the shell which is exposed to the fire, plus

(b) The internal surface of all the fire tubes, plus

(c) The heating surface of the heads, which is to be taken as equivalent to the gross area of one head, less twice the cross-section area of the tubes.

The circumference of a 44-in. diameter boiler would be 44 in. × 3.1416 = 138.23 in. Assuming that one-half of the shell would be utilized as heating surface, one-half of the circumference would be

$$\frac{138.23}{2} = 69.11 \text{ in.}$$

The length being 20 + 12 = 240 in., there would be

(a) 240 × 69.11 = 16,586.4 sq.in.

of heating surface in the shell.

A 4-in. boiler tube has an internal diameter of 3.732 in., hence the internal circumference would be

3.732 × 3.1416 = 11.724 in.

Each tube being 240 in. long, the heating surface of a tube would be

11.724 × 240 = 2813.76 sq.in.,

and for 23 tubes the heating surface would be

(b) 2813.76 × 23 = 64,716.48 sq.in.

The area of one 44-in. head would be

44 × 44 × 0.7854 = 1520.5 sq.in.

Each tube being 4 in. in diameter its cross-sectional area is

4 × 4 × 0.7854 = 12.566 sq.in.,

and twice the area removed by the presence of 23 tubes would be

2 × 23 × 12.566 = 578 sq.in.

Hence the heating surface allowed for the heads is

(c) 1520.5 — 578 = 942.5.

Adding results (a), (b) and (c) gives

16,586.4 + 64,716.48 + 942.5 = 82,245.38 sq.in.,

or

$$\frac{82{,}245.38}{144} = 571.14 \text{ sq.ft. of heating surface}$$

and the boiler would be rated at

571.14 ÷ 10 = 57.1 hp.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for inquiries to receive attention.—EDITOR.]

Engineers' Study Course

Problems in Power-Plant Design--I

By Charles L. Hubbard

Analysis of Problem

In the present article, and those which are to follow, it is proposed to take up the various problems which arise in the design of the power and heating equipment of a large industrial plant.

While details of construction will be considered to some extent, especial attention will be given to the "blocking out" of the general scheme. In plants of this kind, the different parts of the equipment are so related to one another that it is often difficult to decide just where to begin in making the various computations. Methods will first be given for analyzing a problem of this kind, arranging the various requirements under suitable heads, and collecting the necessary working data. After this, the various steps in design will be taken up in their proper order and applied to a practical example, which will be continued throughout the series. Each installment will treat of some particular phase of the subject and will be complete in itself, but at the same time, they will follow in logical order, and taken together, cover the ground with some considerable degree of thoroughness. This series of articles is intended for the practical operating man, and all mathematical work will be given in as simple and condensed form as possible.

General Conditions of the Problem

Let Fig. 1 be the diagram of a proposed plant for the manufacture of general machinery, in which the problem is to work out a general scheme for supplying power, light, heat and water. Certain fixed conditions will be given which must be fulfilled, but within these limits a sufficient leeway will be allowed for a consideration of various methods for accomplishing the same results.

Power—Let the power requirements in the various buildings be as follows: Main shop, 250 hp. delivered at the machines, when all are running together, 150 hp. of this to be furnished by the motors belted to line shafting and 100 hp. furnished by individual motors at the machines.

Foundry—Thirty delivered horsepower, 15 hp. belted to line shafting and 15 hp in motors direct connected to machines.

Forge Shop—Twenty-five delivered horsepower, 15 hp. belted to the line shafting and 10 hp. in direct-connected motors.

Pattern Shop—Twenty delivered horsepower, with motor belted to line shafting.

Carpenter Shop—Five delivered horsepower, with motor belted to line shafting.

The electric power is to be used throughout the plant, partly by motors belted to line shafting and partly by direct drive on individual machines. Air compressors for power hammers in the forge shop and for other purposes are to be motor driven, and are included in the general power requirements above noted.

Lighting—The plant is to be lighted by electricity generated on the premises, the requirements being as follows: The erecting space in the machine shop, foundry, forge shop, boiler and engine rooms, carpenter and paint shops and storehouses are to be lighted with arc lights, while incandescent lighting is to be used in that portion of the machine shop occupied by machine tools and benches, tool room, pattern shop, drafting room and office. In addition to the above, eight arc lights, one to be provided for outside lighting.

Heating and Ventilation—The methods of heating and ventilation employed are to be those best adapted to the various buildings and departments, both effectiveness and economy of operation being considered.

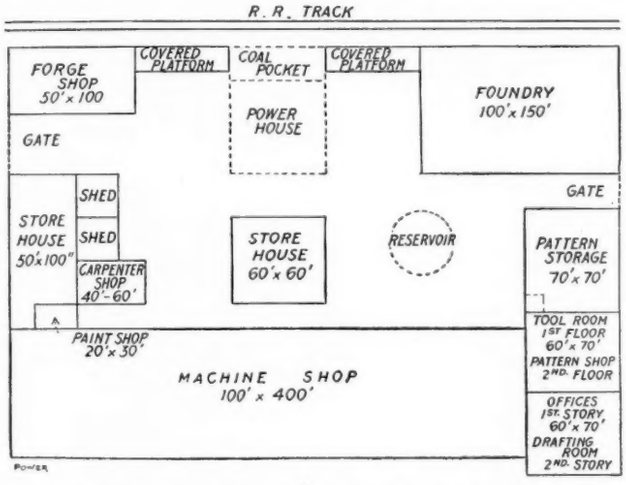


Fig. 1. Diagram of a Proposed Plant

Water Supply—Water for boiler feeding, condensing and fire protection is to be drawn from a river 500 ft. distant, the surface of which is 50 ft. below the boiler-room grade.

General Analysis

The conditions of the problem state that electrical distribution of power is to be employed, which means that the power house may be located independently of the main shop, if desired, as it will not be necessary to belt from the main engine to the line shafting. This item may have a certain bearing upon the arrangements for the handling and storage of coal, steam distribution, water supply, etc. Furthermore, a generating plant must be installed which will supply current adapted to both power and lighting, and sufficient capacity to offset the losses in transmission of mechanical energy into electrical energy and back into mechanical energy again at the machines.

The type of engine must be considered, and computations made to determine the advantages, if any, of compounding and of providing condensing apparatus for

summer use. The type of boilers, mechanical stokers, forced or natural draft, coal-handling machinery, etc., are all matters to be taken up in order. The details of the electrical distribution and of lighting will not be included in the problem, but the power required for this purpose must be computed approximately to determine the capacities of the generators, engines and boiler plant.

The quantity of steam required for heating in the coldest weather must be computed and compared with the available exhaust, before determining the size of the boiler plant. The amount of ventilation, beyond a certain point, will be governed to a certain extent by the amount of exhaust steam. For example, if the supply is less than is necessary for heating purposes in the coldest weather, the amount of ventilation may be reduced at such times, and leakage be depended upon largely to supply fresh air; while if there is more exhaust steam than is required for heating, it should all, or such portion as can be profitably utilized, be employed in improving the ventilation. Before finally computing the quantity of steam required for heating and ventilating, it will of course be necessary to decide upon the type of system to be employed in each building, and the amount of fresh outside air to be supplied in the coldest weather. In determining the size of apparatus, maximum conditions must be assumed, but when computing costs of operation for determining the effect of compounding, condensing, etc., the conditions throughout the entire year must be taken into account.

Comparisons between steam requirements for heating and ventilation, and available exhaust, must be carefully made from day to day, and for different parts of the day when there are considerable changes in load, as during the lighting season. Tables or curves should be prepared showing the relation between power and heating requirements for the entire heating season. It will not usually be necessary to include each day separately, but will be sufficiently accurate for most cases if the season is divided into periods of about two weeks each and average values for these periods used in the table.

The quantity of water required by the plant will depend largely upon whether the engines are to be run condensing during the summer, and cannot be determined accurately until this point has been definitely settled. The distance the water is to be brought, and the elevation or lift, will make it necessary to force it to the plant rather than raise it by suction. To have a supply on hand at all times for fire and other purposes, it will be best to provide a storage reservoir of some form upon the premises and supply this by means of a pumping outfit located at such a point as may be necessary to reduce the suction lift to a height not exceeding 12 or 15 ft. The reservoir should hold at least a day's supply and connect with the various pumps. As the plant is to be of fireproof construction, it will only be necessary, in most cases, to provide hydrants outside and a suitable number of hose connections, with hose attached, inside. In the paint and carpenter shops, pattern shop, drafting room and offices, it would seem best to install automatic sprinklers, as these departments contain a considerable amount of inflammable material.

Available Data

The conditions of the problem already given, and a set of architect's prints of the different buildings, will furnish sufficient data for working out the designs called for. Referring to Fig. 1, the approximate location of the power house is indicated in dotted lines, the dimensions and general arrangement of this are to be determined by the engineer, and the details of construction worked out afterward by the architect.

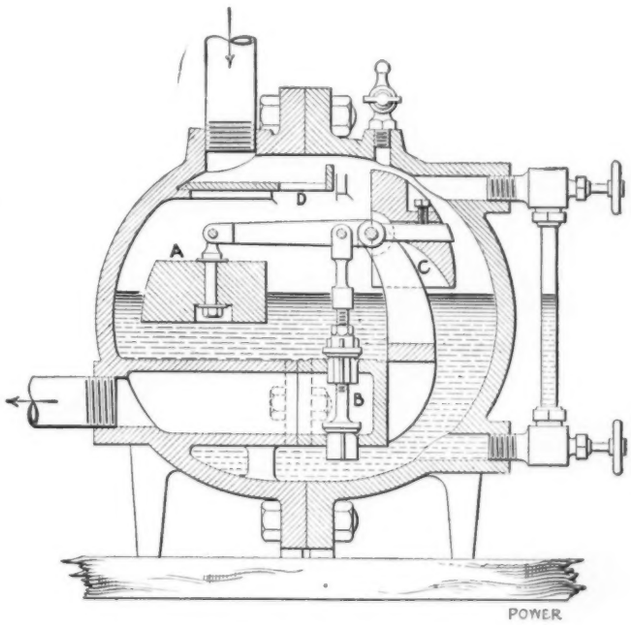
In what follows in the way of design, the chief object to be kept in view is the method of making the computations and the general order in which the different parts of the plant are taken up rather than the exact conditions assumed. These, however, will be made to follow average practice, so far as possible, and sufficient general data will be given to enable the reader to apply the methods to other conditions of a similar nature.

Thoens-Meterie Steam Trap

The Thoens-Meterie steam trap is designed for the discharge of water of condensation at any pressure from 1 to 300 lb. per sq.in.

Its working parts are made of non-corrosive material. Gravity is employed as the motive power. A weight *A*, balanced when half submerged, acting exactly like a float, opens or closes a balanced valve *B*, which is always submerged, thus allowing no escape of steam.

In appearance the body of the trap is spherical and is



Section through Thoens Meterie Steam Trap

so designed that it can be opened without breaking the inlet or outlet connections. The half-submerged weight *A* is made of clinker-burned tile, that is indestructible by heat or water. The counterbalancing weight *C* is of cast iron. The outlet valve is accurately balanced by having both disks of exactly the same diameter. To prevent the inflowing water impinging on the half-submerged weight and thereby disturbing equilibrium, a dash-plate is placed below the inlet pipe.

The trap is a short distance below the vessel or coils to be drained. It is handled by James H. Fogarty, 126 Liberty St., New York City.

OVER THE SPILLWAY

JUST JESTS, JABS, JOSHES AND JUMBLES

"Boilermaker" asks the New York daily press to help subdue the noises in that city. Say, when a boiler maker complains of noise, it's pretty near time to take cognizance!

⁂

"We grieve to prick this brilliant bubble, but our [British] trade is not strangled, our hands not tied, and we are ready to fill orders for all kinds of electrical machinery," says the London "Electrical Review."

This very harsh language is a rebuke to the "Electrical World" and to Doc. Louis Bell for intimating that England is, industrially, "hors concours." Intimators, take notice.

⁂

The New York Electrical show this year frazzles all former efforts. Everything is being done by this popular juice, from resuscitation after a bichloride of mercury tablet to raising chickens and making money. (The money is made by U. Sam in his miniature mint exhibit.) And there are battleships and cows, and hair-raisers and telescribes, and shampoos and pigs, and—well, you have to be there to get it all.

⁂

Says a contemporary about the Kansas City pumping station: Trouble caused by small pieces of waste clogging the lubricators is entirely removed when the oilers use towels. Sure, but did you ever try a hard-boiled sheet or a cotton sock?

⁂

Answering the inquiry, what are the seven wonders of the world? every answer includes "electricity," says the paper. This big wonder makes us wonder how anyone could overlook it.

⁂

Some More from Samoa

There was a young man from Samoa
Who never knew what was in store
When he signed on the ship "Sarah Gore,"
With a hold full of freight for Lahore.

They set him to firing soft coal through a door
That belched heat and flames that scorched him sore,
The like of which never was known in Samoa—
Nor gages that always had trouble in store.

He never had fired before—
And he'll never again—on the "Gore."
Down went that gage near the door
As he dreamed some, and more, of Samoa.

Quick was he wakened and lifted before
The fist of the chief, who felt mighty sore
That he couldn't do murder right there on the floor.

* * * * * *

'Stead of painting the ship with his gore,
They lowered him, pointing to shore—
He's now on his way—to Samoa.

⁂

"What the public wants is a window through which it can look into the affairs of public service corporations," says a traction man.

Yes, and just about the time Public is giving it the once-over, the corporation usually jambs the sash down on his fingers or has him pinched for a Peeping Tom.

⁂

Among the American delicacies now finding favor among the nations of Ceylon are canned fish, face powder and a growing respect for our manufacturers. Looks like the Province of Sabaragamuwa had tipped off the rest of the island to our merits.

⁂

Rep. Nelson of Wisconsin told the House he has ever been a "bloodhound on the trail of the octopus." Must be like one of those sea dogs we saw in Milwaukee diving off a jackknife bridge into the canal after catfish with a diving suit on. Octopuses act real queer if you sit up late enough to watch 'em come up on the bank. It's the only way you can trail 'em.

⁂

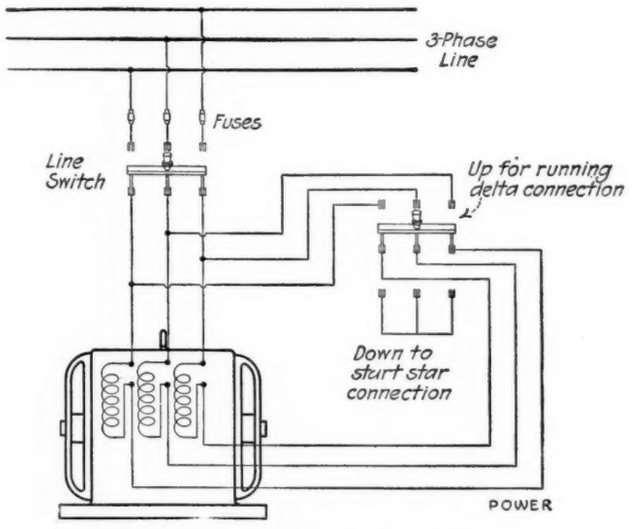
"Japs Have Taken Yap."—Headline.

And what have the Yaps taken—to the tall timber? We can spare a few yaps who, if they could have the running of the plant, would do it so much better than the chief. Somehow, they never get a chance to do much else than yap.

Delta-Star Starting for Induction Motors

By A. L. Temple

There are many cases where the use of an expensive auto-starter for an induction motor of medium size that is started only once a day is a considerable burden of expense and one that the operating man would like to get around. The use of starting and running fused circuits with double-throw switches, which has caused so much discussion with underwriters' inspectors, was devised for this purpose and in many cases works well, if allowed. Another means which seems to work equally as well and one against which the underwriters are not so strenuously opposed, is the delta-star connection of motor-stator windings. The connections for this arrangement are shown in the accompanying illustration. It is required that the phase terminals of the motor windings be brought out to some convenient point so that connections can be made to the line circuits; this, however, is not a serious draw-



Delta-Star Starting Connections

back to the operator, who has some idea of how the stator winding is made up. In case new motors are to be purchased, there is a type on the market that has special arrangements for bringing out the phase terminals.

The working of this arrangement is as follows: With the double-throw switch down, the windings are connected in star and when up in delta. When connected in star the voltage per phase on the motor windings is $1 \div \sqrt{3} = 58$ per cent. of the line voltage, sufficiently low so that the motor starts without an excessive starting current, which is about 1½ times that at full load. Since the starting torque of the induction motor is proportional to the square of the starting voltage, the starting torque for the star-delta method is 33 per cent. of that for the full-line voltage.

The size of switches to satisfy the underwriters when using this means should be as follows: A switch of 30 amp. for ½- to 7½-hp. motors, 100 amp. for 25- to 35-hp. motors and 200 amp. for 40- to 50-hp. motors.

The main objection to this method is lack of starting torque in comparison with the auto-starter.

Freeing the Final Stages of Steam Turbines

By F. R. Low

SYNOPSIS—The principal hindrance in building a steam turbine of very large capacity arises from the immense volume which the steam takes at the low terminal pressures attained and the difficulty of providing area enough in the final blades for this steam to get through without too much residual velocity. The article shows some late attempts of the inventors to meet this situation.

One of the factors which limit the capacity of steam turbines is the difficulty of providing for the great volume which the steam assumes in the final stages.

This volume increases at a rapid rate as the pressures diminish to those existing in the final stages with the high vacuums now sought. A pound of dry-saturated steam at an absolute pressure of 230 lb. occupies a volume of about 2 cu.ft. In a vacuum this increases, in round numbers, as follows:

Vacuum in Inches of Mercury	Absolute Pressure In. Mercury	Volume, Cu.Ft. per Lb.	Relative Volume, 2.004 = 1
20	10	75	37
22	8	92	46
24	6	120	60
26	4	176	88
28	2	339	169
29	1	654	326
29.5	0.5	1257	627

If the steam, at 230 lb. absolute and dry-saturated to start with, were still dry-saturated after being worked to a vacuum of 29.5 in., its final would be 627 times its initial volume. This is modified considerably by the fact that the initial volume will be greater if superheat is used and that a considerable percentage of the steam is condensed during expansion, but not so much as would be if the expansion were adiabatic on account of the carrying of some heat to the lower stages by conduction and to the generation of heat by eddy and friction. The accompanying table gives the approximate volumes in cubic feet for steam of various initial pressures and degrees of superheat expanded to the pressure corresponding to 85 degrees F., 0.594 pound per square inch.

INITIAL AND FINAL VOLUMES AND RATIOS OF EXPANSION OF STEAM EXPANDED ADIABATICALLY TO 85 DEG. F.

Pressure Lb. per Sq.In. Absolute	Superheat, Deg. Fahrenheit 0	50	100	150	200	250	
	4.43	4.79	5.14	5.47	5.80	6.12	Initial volume
100	427	437	445	453	460	467	Final volume
	96	91	87	83	79	76	Ratio of expansion
	3.73	4.04	4.33	4.62	4.89	5.17	Initial volume
120	423	433	441	449	456	463	Final volume
	113	107	102	97	93	90	Ratio of expansion
	3.22	3.49	3.75	4.00	4.24	4.48	Initial volume
140	419	429	438	445	453	459	Final volume
	130	123	117	111	107	102	Ratio of expansion
	2.83	3.07	3.30	3.53	3.74	3.95	Initial volume
160	416	426	435	442	450	463	Final volume
	147	139	132	125	120	117	Ratio of expansion
	2.53	2.75	2.96	3.16	3.35	3.54	Initial volume
180	414	424	432	440	447	454	Final volume
	164	154	146	139	133	128	Ratio of expansion
	2.29	2.49	2.68	2.86	3.04	3.21	Initial volume
200	411	421	430	437	445	451	Final volume
	180	169	160	153	146	140	Ratio of expansion
	209	228	2.45	2.62	2.78	2.94	Initial volume
220	409	419	428	435	442	449	Final volume
	195	183	175	166	159	152	Ratio of expansion
	192	2.09	2.26	2.42	2.57	2.71	Initial volume
240	407	418	426	434	441	447	Final volume
	212	200	189	179	172	165	Ratio of expansion
	1.78	1.94	2.10	224	239	2.52	Initial volume
260	405	416	424	432	439	445	Final volume
	228	217	202	196	183	180	Ratio of expansion

Of the group of three figures for each initial condition of pressure and superheat, the first is the initial volume in cubic feet per pound; the second, the volume after adiabatic expansion to 85 degrees F., and the last, found by dividing the second value by the first, the ratio of expansion or the number of times the final volume is as great as the initial. Notice that the *higher* the initial pressure or superheat, the smaller the final volume. This is because, starting with more pressure or superheat, the steam does more work with consequently greater heat conversion and condensation, a less percentage of it being steam even with its higher initial heat content than in the case of the lower initial pressure or temperature.

These figures are theoretical, based on adiabatic expansion. As the result of all the departures from this mode of expansion—except the inconsiderable loss due to radiation—is to carry the heat to the lower stages and add it as heat to the acting steam itself, the actual final volumes and ratios of expansion are even greater than those shown here.

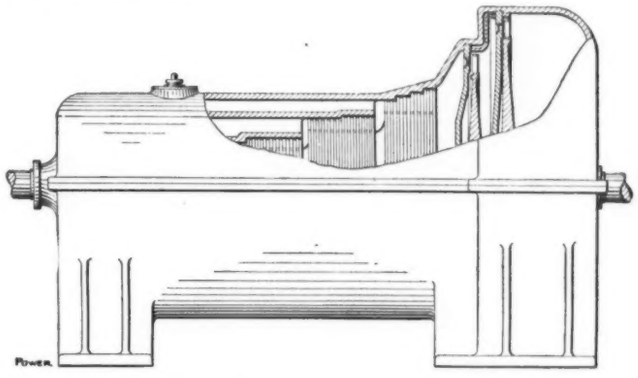


FIG. 1. R. H. RICE'S SUGGESTION OF ENLARGED FINAL DISKS

Allowing the final volume of a pound to be 450 cu.ft. and the steam rate 12 lb. per kilowatt-hour, a turbine generating 30,000 kw. would discharge

$$\frac{450 \times 12 \times 30{,}000}{60 \times 60} = 45{,}000 \text{ cu.ft. per sec.}$$

In order that the efficiency of the later stages may not be impaired, this great volume must flow through the blades with a velocity not greatly exceeding twice their own peripheral speed. This speed is limited by considerations of centrifugal force and quiet running in the direct-connected generator as well as in the turbine itself. At the same time the size of the passage, determined by the length of the blades, is restricted by the mechanical difficulties attending the use of blades of great length, and by the fact that if the blade is too great a proportion of the radius, there will be too great a discrepancy between its root and tip speeds, so that if the ratio between the velocity of the steam and that of the middle of the blade is correct, it will be too low for the tip and too high for the root.

The struggle is therefore to get greater peripheral velocity for the final blades and greater section through them in order to keep the ratio between the steam and blade velocity down to the proper point.

It is the custom of all builders of reaction turbines that are designed for 28-in. vacuum, or better, to change the angles of the last one or few rows of blades, increasing the angle with the direction of motion, say, using an angle of 40 deg. instead of 20, Fig. 6, and by this means doubling the area of passage way at some sacrifice of hydraulic efficiency. The blade thus produced is often referred to as the "wing" blade. It is understood, of course, such a machine designed for high vacuum, 29-in. for example, the last row of blades may require to have nearly double the blade area of the preceding row.

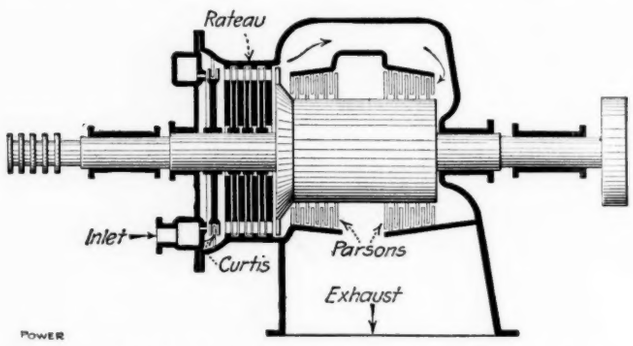


FIG. 2. PAPE'S TURBINE WITH VELOCITY PRESSURE AND REACTION STAGES

Richard H. Rice, manager of the General Electric Co. at Lynn, Mass., in a recent patent attacks the problem by increasing the diameter of the final element, as shown in Fig. 1, gaining thus both peripheral speed and greater area through the blades. He suggests one or more impulse wheels each carrying preferably but a single row of buckets, operated in the usual way with nozzles located in the diaphragms which inclose such stages. These impulse wheels or disks can be made of sufficient diameter to give a peripheral speed approximately correct for the best efficiency; that is to say, about one-half of the velocity with which the steam flows. Moreover, the impulse wheels require no balancing drum or dummy pistons and are much lighter than the blade-carrying drum would be.

Wilhelm Pape, of Charlottenburg, Germany, has just assigned to the General Electric Co. a patent for the ar-

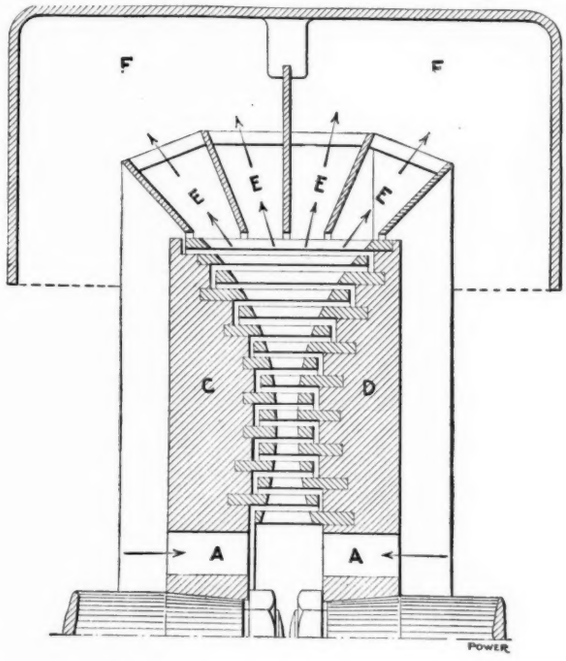


FIG. 4. LUNGSTRÖM'S DIFFUSER

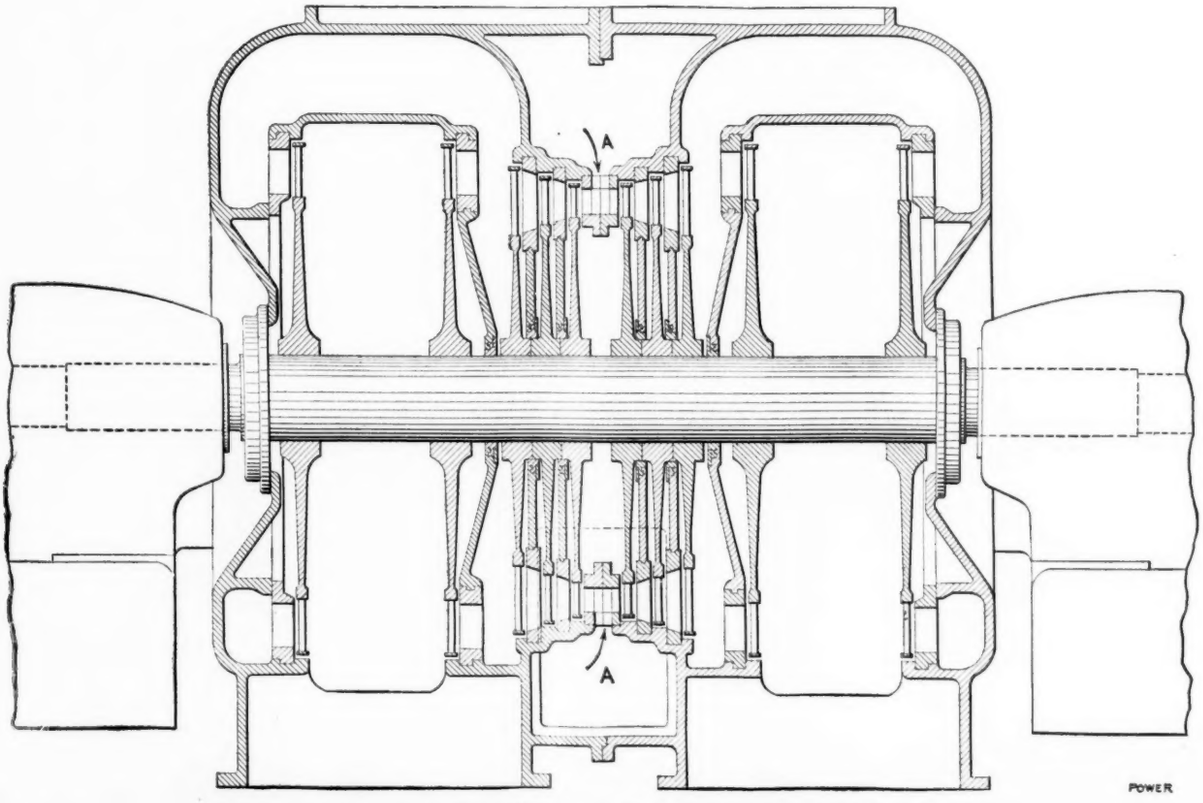


FIG. 3. JUNGGREN'S LOW-PRESSURE TURBINE WITH TWO-WAY EXHAUST

rangement shown in Fig. 2, in which all three types of blading are used, initially a high-pressure velocity stage (Curtis); next, pure pressure-impulse stages (Rateau), and finally, reaction stages (Parsons). The engraving shows the reaction element as double-flow, exhausting in the center. This eliminates the necessity for balancing plates or dummies, but the patent specifications show it both single- and double-flow. Due to the use of the intermediate pressure stages, the reaction stages may be of liberal proportions, especially as regards the diameter at the inlet, and the total number of such stages can be made relatively small. We mentioned in 1910 a turbine comprising these three types of blading said to have been designed by Prof. Beluzzo and built by Gadda Finzi & Co., of Milan.

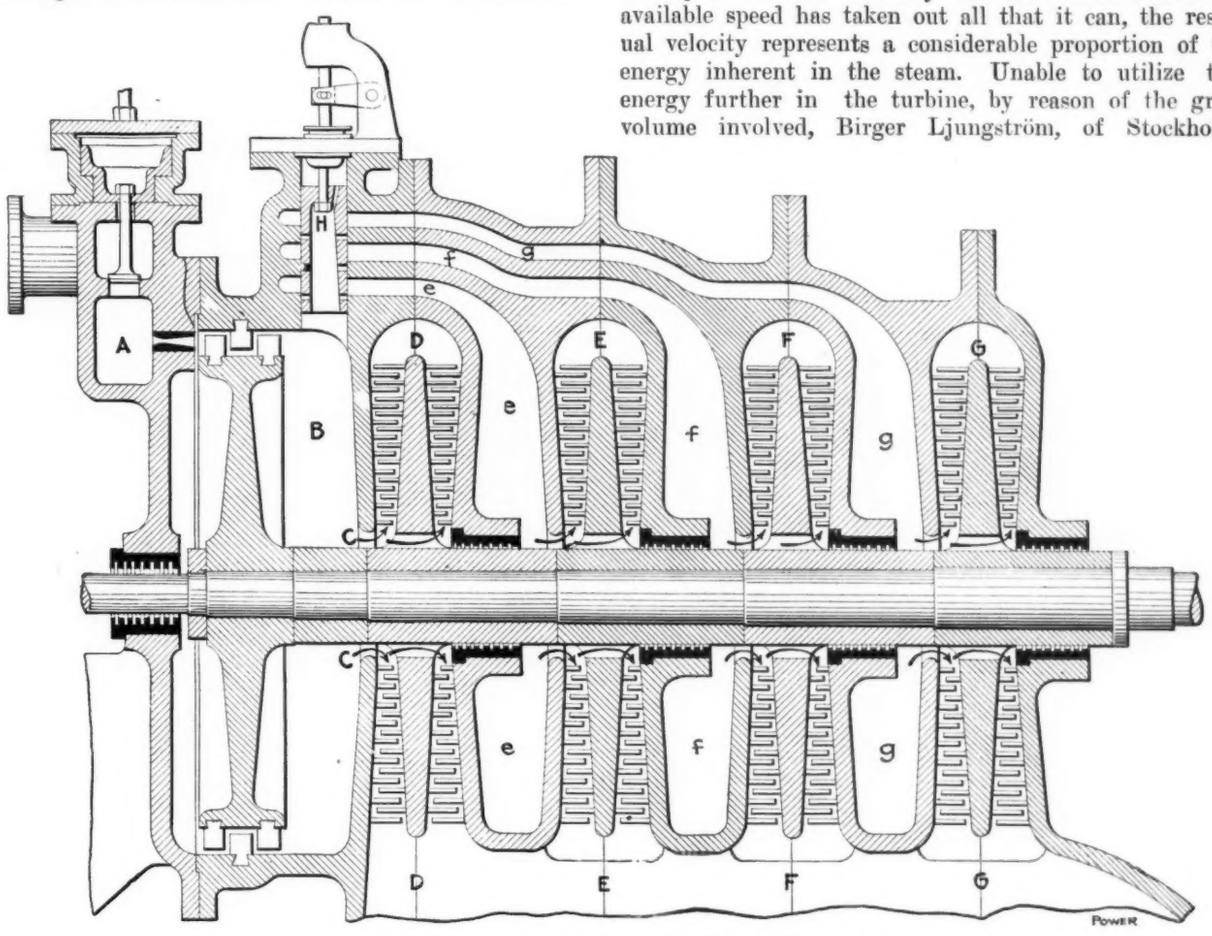


FIG. 5. LONDON'S SECONDARY-STAGE TURBINE

Since 1907 the Westinghouse Machine Co. has built turbines for certain ranges of capacity, having an impulse element for the high-pressure followed by a single-flow reaction element, this again followed by a double-flow reaction element, the latter expanding from approximately atmospheric pressure to that of the condenser, all this for the purpose of being able to handle the rapidly increasing volume of steam in the low-pressure range.

Oscar Junggren, turbine designer of the General Electric Co., at Schenectady, has patented the arrangement shown in Fig. 3 for low-pressure turbines. After leading the steam, which enters at *AA*, through the first few stages of a divided-flow turbine, it is directed at each end of such turbine against bucket wheels operated in parallel so that without any excessive increase in the diameter of each wheel or unwieldy lengthening of the buckets, the available bucket area is doubled in that stage. In effect, it amounts to another division of each subdivision of the divided-flow turbine, so that during the concluding portions of its passage the steam has four parallel paths instead of two.

In order to get the steam through the final stage, it must pass with such velocity that after the wheel at the available speed has taken out all that it can, the residual velocity represents a considerable proportion of the energy inherent in the steam. Unable to utilize this energy further in the turbine, by reason of the great volume involved, Birger Ljungström, of Stockholm, Sweden, uses it to bat back the pressure beyond the final wheel, and thus to enable the final expansion to extend to a pressure lower than that which exists in the condenser itself. In Fig. 4, reproduced from a patent recently issued to Mr. Ljungström, the steam entering at *AA* flows through the blades, which are fashioned so as to form a nozzle adapted to the ratio of expansion for which the turbine is designed. The disk *C* to which one set of blades is attached revolves in one direction, and the disk *D* holding the alternate blades, in the other

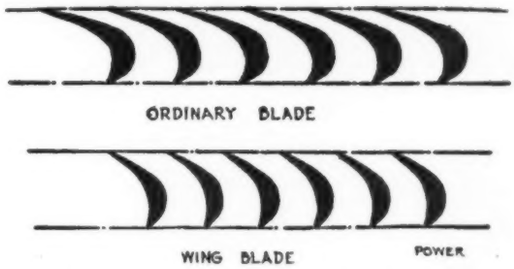


FIG. 6. COMPARISON OF BLADE ANGLES

direction. As the steam leaves the last blade it is discharged at considerable velocity into the diffuser passages *EEEE*, repelling the pressure which exists in the spaces *FF* connected to the condenser. The pressure in the last blade may, therefore, become by expansion less than that which the condenser is able to maintain.

W. J. A. London, of Manchester, England, runs a lot of secondary reaction stages in parallel behind a single initial Curtis velocity stage wheel. Steam enters at *A*, Fig. 5, through a series of nozzles of which the governor opens more or less, letting in more or less steam according to the load. The steam discharged from the Curtis blading passes into the chamber *B*, and thence through the passage *C* to the reaction element *D*. As the amount of steam admitted becomes so great that this reaction element cannot take it all away and pressure commences to build up in the chamber *B*, the valve *H* is lifted, opening successively the passages *e*, *f* and *g*, permitting the escape of the steam to the elements *E*, *F* and *G*, which are automatically brought into action according to the amount of steam flowing.

Status of Automatic Stokers*

BY R. J. S. PIGGOTT

The principal considerations in the design of a stoker are:
Coking of green coal,
Adequate mixture and heating of volatile matter with air,
Burning of fixed carbon,
Disposal and dumping of ash and clinker; other points, only less important than the first four are,
Prevention of sifting,
Prevention of clinker adherence to brickwork and stoker parts.

OVERFEED STOKERS

The principal overfeed types of stokers are the Roney, Wilkinson, Wetzel, Murphy, Model, Detroit and Lehigh. The Roney step grate has renewable fingers as a grate surface; the Wilkinson, hollow stepped bars from top to bottom of the furnace; the Wetzel has bars from top to bottom of the furnace, with lugs cast on the sides to retain the coal; the Murphy, Model and Detroit are almost alike, having bars similar to the Wetzel, but two grates set opposite to each other in the form of a "V" with a coking arch over the whole. In addition, a set of clinker rolls or crushers is added at the bottom of the "V."

In all of these stokers, coal is pushed in at the top of the slope and coked by the aid of a firebrick arch, progressing down by the motions of the grate bars, aided by gravity. In all, the upper portion of the bars is arranged to retain the uncoked fine coal upon the grates, changing to larger and freer openings in the lower two-thirds, where the coal has fused into larger bodies, and the combustion is chiefly that of fixed carbon. The clinker is collected at the bottom and there crushed by rolls or dumped.

The coking action is confined to a zone at the top of the furnace and must necessarily generate a copious volume of hydrocarbon gases which cannot be adequately and intimately mixed with air; because the green coal packs closely and is almost impervious to air, under slight differences of pressure; so that the air for burning the volatile matter must be supplied either from the air openings in the arch, or from excess air admitted through the lower portion of the grates. In the short distances from the grate to the tubes, except in such boiler settings as the Stirling, the time between leaving the grate and reaching the tubes is too short to allow thorough mixing of the gas and air; so that cooling occurs before the gases can mix and burn, and incomplete combustion results.

The burning of fixed carbon is easy, as coking leaves it more or less open and porous, and the fusion of siftings into larger masses allows plenty of air to be admitted. In fact, the usual operation permits a considerable excess of air at this portion of the grate. The evidence is to be found in the smoky red flame passing up through the tubes over the coking zone, changing through yellow to blue and finally to the clear and almost flameless fire indicating excess air at the dump-grate end.

The accumulation of excessive clinker must be prevented by slicing and periodic dumping; if left for long periods to burn out all combustible, the clinker is liable to be large and hard to dislodge. If dumped at short intervals, the combustible is not all burned out. The roll crusher employed in the V-types is apt to give trouble from adhering clinker and refusal to grip large clinkers, necessitating excessive barring.

Sifting to the extent of 5 to 8 per cent. occurs in all overfeed stokers, depending on the air space allowed and the length of time the stoker has been in use. In all the overfeed stokers, since the hot fixed carbon combustion occurs directly on the grates, burning of iron is considerable, especially with high sulphur coals. The pyrites and sulphur have a fluxing action on the iron. Once the clinker gets down to the iron, and the bar becomes overheated, the whole bar may melt and run down in a few minutes, by what appears to be a catalytic action.

Any of these stokers will operate with fair efficiency and little trouble from clinker and burning, if operated at their proper capacity, as rated in pounds per square foot of grate area. At the present time it is considered good practice to provide sufficient stoker capacity to operate the boilers at 200 per cent. of rating continuously.

CHAIN-GRATE STOKERS

The chain grate group, such as the Green, Babcock & Wilcox, Illinois, Coxe, Mackenzie and Laclede constitute a successful type for the burning of a certain class of bituminous coal, namely, high volatile (30 to 40 per cent.) and high ash (10 to 20 per cent.). They are subject to many of the slope-grate overfeed drawbacks, but have additional advantages. Coking occurs in a zone at the entrance to the stoker, but as the coking arch is much longer than for the slope-grate types, the mixing of air and volatile matter is more effective, and less loss due to incomplete combustion of gases results. The burning of fixed carbon is accomplished in the same way as on the slope-grate overfeeds. Clinker troubles are reduced, as the grates are entirely cleared of ash and clinker, and cooled by the return on the under side, once every complete revolution of the grate.

The ash and clinker dump automatically at the water or air-back, and no hand slicing is necessary. Labor is therefore less than for the slope-grate overfeeds. One stoker operator is required to four Roney type stokers of 500 to 600 hp. rating, and one coal passer for about every five or six stokers. One stoker operator and one coal passer can handle about ten chain grates.

The weight of the chain grate is the highest of any type. For instance, a Roney stoker for a 600-hp. B. & W. boiler, 12 ft. 6 in. width of furnace, weighs 30,000 lb.; a Green type-L chain grate for the same furnace weighs 80,000 lb.; the Illinois stokers weigh from 60,000 to 82,000 lb., depending on the type, and a Taylor underfeed with extension grates, 32,000 lb.

The forcing capacity of the chain grates is somewhat higher than that of the slope grate overfeeds, except the Wilkinson and Lehigh, since forced draft can be employed as well as natural draft; however, it has not been very successful to use forced draft with certain kinds of coal. The maximum boiler rating obtainable ordinarily with the Roney or Murphy types is 190 per cent. of rating, with a combustion per square foot of grate of not over 35 to 38 lb. of coal per hour. General practice does not exceed 150 to 175 per cent. of rating. This limitation is partly on account of natural draft, and partly maintenance. Natural draft higher than 1.5 in. of water is practically out of the question, and burning of the grates at higher rates of driving becomes excessive.

The chain grates are generally larger in area for the same boiler, and the forcing capacity will reach 260 per cent. of boiler rating, with combustion rates up to 45 to 48 lb. These results apply chiefly to the use of coal suited to the stoker. With low ash coals at these rates of driving, the grates become overheated, and breakage, with the attendant high maintenance and unreliability, is sure to result.

For the burning of such coals as described, the chain grate gives eminently satisfactory results; but for low ash coals it is practically a failure.

UNDERFEED STOKERS

The underfeeds are represented by the Taylor, Riley, Westinghouse, Jones and American. The Jones has usually a single horizontal retort per furnace, spreading coal by a ram, from the center to the sides of the furnace; there may be two or more retorts for wide furnaces. It has only

*From the report of the Committee on Power Generation, presented before the Engineering Association of the American Electric Railway Association at Atlantic City, Oct. 12 to 16, 1914.

recently been provided with means for dumping into an ashpit.

The American has a single central horizontal retort, and movable grates somewhat similar to the Murphy stoker, with dump plates at each side of the furnace. The Taylor, Riley and Westinghouse have several retorts per furnace, according to the width of the setting. The retorts are alternated with rows of tuyeres for supplying the air and the whole is set at an angle of 20 to 25 deg., using gravity to aid the working of the clinker and ash to the back of the furnace. The green coal is fed from under the surface of the fire by the rams: it spreads over the tuyeres through which the air is forced, and as it approaches the surface of the fire is coked by the burning of fixed carbon and volatile matter in the upper layer. The volatile gases, closely mixed with the air, pass through the incandescent coke before reaching the combustion chamber. The process has radical advantages over the overfeed method; first, because green coal or only partially coked coal covers the tuyeres, so that burning of the iron is practically eliminated; second, there is distillation of the volatile matter over nearly the whole area of the furnace; third, immediate and intimate mixture of the whole air supply and volatile matter while still in the coal bed; fourth, passage of mixed volatile and air through the hottest zone of the fire (burning coke and gases) before reaching the furnace; and fifth, the elimination of all arches. The essential conditions for perfect combustion of volatile matter are intimate mixture with air, and high temperature; the underfeed method meets these conditions very well. The fixed carbon is not quite completely burned in this process, so that a short section, termed an extension grate, is added to the bottom of the tuyere and retort section, and the combustion of fixed carbon is completed on these grates in the same manner as an overfeed. Finally the clinker arrives in the dump plates (in the Taylor) or is expelled by continuous dumping and crushing devices (a moving extension grate and apron in the Westinghouse, and a moving apron in the Riley).

The Westinghouse stoker differs from the Taylor very little in general design, except in the use of the continuous dumping device, and an air-cooled bridge supporting the front wall. The Riley stoker differs from the other two in moving the tuyeres bodily and in having more overfeed effect. The underfeed stokers are essentially forced draft stokers, as they operate with restricted air openings and very deep fires. The Riley and Westinghouse can be operated with natural draft of 80 to 90 per cent. of rating, but this is not generally desirable. On the Taylor stoker the fires run from two to four feet thick, depending on the rate of driving, whereas the Riley, having more overfeed effect, seldom exceeds one to two feet. The forcing capacity is enormous, reaching as much of 400 per cent. of rating at 80 to 85 lb. per square foot of grate. Three hundred per cent. of rating is readily obtained continuously at from 60 to 65 lb. of coal per square foot of grate. One man can operate ten or twelve stokers: siftings are negligible, amounting to 0.2 per cent. or less, requiring clearing of the windbox and retorts about once a month. The brickwork at high ratings suffers somewhat from the adherence of clinkers to the side walls and the bridge wall, but there are no arches required, and arches are the most expensive and troublesome of all brickwork in the furnace.

Thirty-Fifth Anniversary of Electric Lighting

Oct. 21 will commemorate the 35th anniversary of the invention of the incandescent lamp by Thomas A. Edison. This day in 1879 may be said, broadly speaking, to mark the birth of electric lighting. Arc lamps had been in use some years previous but only a few were then employed, for searchlights, to light theaters, parks, street corners and similar public places. The universal lighting of both public buildings as well as private dwellings by electricity through small units became a dream realized only when Edison first successfully made his electric filament bulb glow in his laboratory at Menlo Park, N. J., 35 years ago.

In 1880 an employee of the Edison factory carried all the electric incandescent lamps in the world from Menlo Park to New York City in a market basket. A year later it was considered a wonderful feat when the small factory turned out a thousand lamps a day. Today, the great Edison lamp factory at Harrison turns out 35,000 lamps an hour and will have made in all more than 500,000,000 lamps during the period of the phenomenal progress of electric lighting up to the present time.

Dr. Charles P. Steinmetz, the wizard of electricity and chief consulting engineer of the General Electric Co., in giving the essence of his appreciation of Mr. Edison, said:

"The first time I met Edison was in 1893, at the International Electrical Congress in Chicago. Mr. Eickemeyer introduced me to him, and Edison, jokingly pointing at me, said, 'Pure theory'; pointing at Eickemeyer, 'Theory and practice,' and at himself, 'Pure practice.' This is the attitude Edison has always taken, declaring himself a mere practical man. Some have expanded on this and so created the popular belief that Edison does not know anything about theory and science, but merely experiments and tries everything he or anybody else can think of. There is nothing more untrue than this, and Edison probably never made an experiment or tried something where he did not have a good theoretical reason that would justify the trial even from a strictly scientific standpoint."

We are all more or less familiar with the events of the romantic life of Edison, the boy, who only really went to public school three months, was given up by his teachers in despair because he was always at the foot of the class, was taught by his mother; installed a laboratory in the cellar of his home; started in business as a newsboy on trains of the Grand Trunk to get money for scientific books and equipment for his laboratory; installed another laboratory in a baggage car of the train and was thrown off because one of his dubious experiments set fire to the car; became a telegraph operator; began to invent and became the greatest inventor of the age, having taken out no fewer than 1328 separate patents from 1869 up to the summer of 1910. The height of his activity was in 1882 when 141 patents were applied for.

The events connected with the invention of the electric incandescent lamp are especially interesting.

In the search for the right material that should make the incandescent lamp a feasible, profitable commercial proposition, all kinds of pastes were tried as bases for dependable carbon filament; also cotton thread, paper and anything that would carbonize readily and hang together as a "filament" when the electricity was turned on.

For nearly 10 years the Edison lamp was made with bamboo filaments; and to that lamp must be attributed in a large degree the marvelous development of electric lighting and power all over the world, as well as the creation of the modern central-station industry, which in the United States alone represents an investment of over $2,500,000,000 and annual earnings of over $350,000,000. Even as late as 1908, a few special types of Edison bamboo lamps were being made.

Paralleling the carbon filament lamps of bamboo, there appeared the "squirted" filament, employing carbonized cellulose, and a great many lamps for a number of years were of this type. Another advance was embodied in lamps still of the carbon type, in which the filaments were strengthened by such substances as would justify calling them "metallized." In particular, the metal tantalum seemed to stand out from the rest of the group, but it was never a strong competitor of the carbon lamp. The solution was soon found in tungsten, a metal tried as far back as the earlier days of Edison, but not then available under the practical conditions of its production and use.

The introduction and general adoption of the Mazda tungsten lamp has been literally nothing short of a revolution in the art of interior illumination, with a correspondingly tremendous effect on exterior lighting. Working down from a consumption of four or five watts per candlepower in carbon filament lamps to the standard a few years ago of 3.10 watts per candlepower, the Mazda lamp has brought that down in about five years to 1.25 watts; while in the larger sizes of gas-filled lamps, the reduction in current consumption has reached the low point of a half-watt per candle.

The intimate history of the birth of the electric incandescent lamp is best told by W. H. Meadowcroft, who was associated with Edison when he produced the lamp:

"Business was getting fairly well under way when I assumed my duties at 65 Fifth Ave., New York. The back parlor was used by Major Eaton as his office; on the second floor was Charles L. Clarke, the chief engineer with H. M. Byllesby at the drafting board; Edward H. Johnson had part of the same floor with E. T. Greenfield as the foreman of his wiring gang; and a good part of the third floor was used by Mr. Edison as his office and headquarters, with Samuel Insull, recently from London, installed as secretary. On the third floor there was also the patent department, where Col. Dyer and several assistants were kept busy day and night making applications for patents on the flood of inventions that was constantly pouring in.

"Those were strenuous days for Mr. Edison. Besides the enormous amount of work entailed by the operations of his manufacturing shops, he was elaborating the engineering plans for the first central station in New York City, covering carefully every detail; he was turning out several new inventions every day, and helping the Board of Fire Underwriters formulate rules for the new art of incandescent lighting. He was also working on the innumerable details relating to isolated electric lighting plants, for which there was beginning to be a demand. He was directing the engineering and construction work of his electric railway out at Menlo Park, besides directing the policy of the company with the far-sightedness that experience has long since justified. He was working about twenty hours a day at this time, and how he ever got through so much work and accomplished so much is a mystery to me even at this day. He seemed to be utterly oblivious of the every day things of life. When he seemed to need new clothes, Mr. Insull would order them and have them delivered to Mrs. Edison. When they arrived she would wait until he had gone to bed and then change all his things over from the old suit into the pockets of the new one and leave that where he had left the old suit. He would put it on the next morning and was likely to go down to the machine works or elsewhere and get the new clothes covered with oil or chemicals.

"The selling price of lamps in the early days was 80c. each. It cost over a dollar to make them, and the financial men were worried. They couldn't see any further, but Mr. Edison did. He said in effect: 'Give me an exclusive license to manufacture during the life of the patents and I will agree to supply all the lamps you need at 40c. each.' They jumped at the chance and the contract was made. Mr. Edison lost money steadily for three years, but owing to improvements in manufacture and to the rapid development of the business, he made more money in the fourth year than he had lost in the three preceding years."

New York Electrical Show

The New York Electrical Exposition and Motor Show opened at the Grand Central Palace on Oct. 7 and closed on Oct. 17. The attendance was large. About a hundred companies and societies were the exhibitors.

The United States Government had a number of noteworthy features. The various uses to which electricity is being put in the manufacture of cartridges was shown in an exhibit from the government arsenal at Frankford, Penn. The different processes were demonstrated, from the drawing of the brass shell to the loading and fixing of the steel-jacketed bullet. An interesting piece of apparatus of the army exhibit was a hand-operated generator for use by the signal corps. This machine is operated by two men and supplies sufficient energy for a field wireless outfit. Navigating appliances, steering devices and a signal system make up part of the naval exhibit. The wireless equipment of a ship-of-war was demonstrated by a class from the Brooklyn Navy Yard. What is left of the lighting generator used on the United States ship "Maine," which was destroyed in Havana harbor, was also on display. The Treasury Department had a fully equipped mint from the United States establishment in Philadelphia, showing the whole process of coin production from the melting furnace to the stamping and weighing machines.

Among the commercial and industrial booths were the Edison Electric Illuminating Co. of Brooklyn, the New York & Queens Electric Light & Power Co., the New York Edison Co., and the United Electric & Power Co. The Westinghouse Electric & Manufacturing Co. and the General Electric Co. and its affiliated concerns were also well represented. Numerous other manufacturing companies had booths, and practically every phase of the electrical industry was represented in one way or another.

Denies International Power Co. Is Insolvent

Joseph H. Hoadley, formerly president of the International Power Company, denies the insolvency of that corporation in an eighty page affidavit presented to Chancellor Walker at Trenton, N. J., on Oct. 6. He insists that the assets exceed the liabilities by at least $3,000,000 and argues that a receiver should not be appointed.

Mr. Hoadley denies that he speculated in the stock of the company, but admits that about twelve years ago he did buy and sell the stock with a view of creating a market for it and maintaining the price. He insists, however, that he was acting under the authority of the directors for the company itself.

Admitting that numerous changes had been made in the books of the company last December, Mr. Hoadley asserts that the alterations were merely corrections designed to present the true condition of the company's affairs, and were not designed to make it fraudulently appear that the company was indebted to him instead of his being heavily indebted to the company. He says he never has pressed the company for settlement of a claim of $50,000 which he holds against it.

Mr. Hoadley explains that the reason for his retirement as a director of the company was to give the board entire freedom to act for the benefit of the company, even though it should involve bringing a suit against him personally. Counsel for Henry W. Bull, who is fighting Mr. Hoadley, intimated that the new board would be as completely under the domination of Mr. Hoadley as the old board.

Chancellor Walker said he would give both sides further opportunity to present evidence.

Water-Hammer Ruptured Valve Bonnet

A gate valve bonnet ruptured on a 15-in. underground main steam line along Dey St. between Church St. and Broadway, New York City, Tuesday morning, Oct. 6, just before 7 o'clock.

It appears that the valve had been closed in order to make some repairs to the line beyond and was being opened at the time the failure occurred. The valve bonnet was split at right angles to the line, showing signs of water-hammer. As the pressure carried is about 90 lb., the force of the blow was terrific and the escape of steam through the valve box was so rapid that the workmen who were operating the valve were unable to escape before being severely scalded about the hands and face. The pipe line is a part of the steam distributing system of the New York Steam Co., which supplies steam heat for numerous large buildings in that section of the city. Prompt action on the part of the company restored the service in a short time.

Electric-Plant Heater Explodes

A feed-water heater in the city electric light plant of Newark, Ohio, exploded at about 7 o'clock p.m., Oct. 1, and the body of the heater was projected through the roof. Although the engineer and fireman were both in the room at the time neither one was injured. The heater had been in use more than 20 years, and as the feed water is extremely bad it is likely that the inside of the piping had become so scaled up that excessive pressure was necessary to force the water through.

Revolts against Electric-Light Contract

C. L. Wooldridge, superintendent of buildings, Pittsburgh, Penn., is preparing estimates of the cost of establishing plants in at least five school buildings to make their own power. The board of public education, lighting most of its 132 school buildings with electricity, and using it liberally in many buildings for operating machinery in the shops, considers it is one of the largest patrons of the Allegheny County Light Co. in the city, but has been unable to obtain a reduction in the price below 5c. a kilowatt-hour for light, and 3 to 2½c. a kilowatt hour for power.

The principal objection voiced by board members and Carl M. McKee, superintendent of supplies, through whom the contracts are made, is that, in fixing rates, each school is considered as a unit and charged separately, whereas the board has been insisting that the entire school system be considered as a unit and charge made accordingly.

Bakersfield Steam Power Plant—In the article describing this installation, on page 476 of the Oct. 6 issue, the fact that the data and photographs were furnished by the J. G. White Engineering Corporation, New York City, was not incorporated. They were also the engineers who constructed the plant.

The third annual gas-power show of the National Gas Engine Association will be held in Toledo from Oct. 19 to 24. A feature of the program this year will be an engine and food-grinding contest under the direction of the farm power committee. In this connection a series of tests will also be conducted by the American Society of Agricultural Engineers.